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COASTAL DUNES: THEIR FUNCTION, DELINEATION, AND MANAGEMENT

Center for Coastal and Environmental Studies

New Jersey Department of Environmental Protection, Division of Coastal Resources

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COASTAL DUNES: THEIR FUNCTION, DELINEATION, AND MANAGEMENT

by

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Executive Summary

Similar to their counterparts in other areas of the United States, inhabitants of New Jersey's coastal areas are faced with shoreline erosion and its concomitant effects. Substantial efforts have been made in this state to reduce the problem, but people are discovering that traditional methods are expensive, and at best they only slow erosion. The underlying causes of shoreline erosion, a rising sea level and decreased sediment sources, cannot in most instances be controlled. An alternative approach to the problem is to manage the use of the coastline in a manner which is compatible with the natural forces that shape the coastline. The management area is to be located in the dune zone because of certain protective properties associated with these dunes. First, dunes provide a natural barrier to flooding during coastal storms. Secondly, dunes represent storage of sediment which can be released during storms and which can be used to build beaches. Finally, dunes offer other advantages in terms of coastal aesthetics and wildlife habitat.

The establishment of a management area must be based on scientific theory and on empirical data. It is important to recognize that the beach/dune system is migrating inland in response to natural processes. Any management zone created along the shore must, therefore, be allowed to migrate with the system. Furthermore, the management area must be designed so as to allow the processes which produce migration to function without interference.

This study presents a dune management model which includes the creation of a Dune Management District and the identification of practices which should be encouraged within the district. Because the establishment of this district is based upon natural protection advantages offered by the dunes, it is necessary initially to determine how much protection is desired. A design storm with a 50 year recurrence interval is adopted as the basis for protection requirements. A design dune is constructed to protect against conditions associated with the 50 year storm. This dune has specific height and width dimensions which are established through the use of an accepted scientific methodology. Because the characteristics of beaches vary spatially, the New Jersey shoreline is divided into four segments, each of which has specific characteristics. The dimensions of the design dune are established for each of the four segments.

In order to account for shoreline migration within the model, the historical rates of erosion for particular stretches of the shoreline have been utilized. A basic assumption is that the historical rate of shoreline migration will continue at the same rate in the future. Given the fact that the shoreline is migrating inland, it is necessary to establish a zone to the lee of the dunes into which the dune may migrate. The width of the migration zone is a function of the rate of erosion.

The design dune dimensions and the erosion rate are combined to establish the width of the Dune Management District. The Dune Management District comprises both the dune and the migration zone. In order to determine the width of the District, it is first necessary to decide on the temporal limits for the operation of the District. In this study, it is assumed that the planning period is 10 years. The rate of migration is determined on the basis of this time factor by multiplying the annual erosion rate by the number of years in the planning period. Dune width and the 10 year predicted migration distance are added together to give the width of the Dune Management District.

The Dune Management District is a band which is on the order of 200 feet wide. The seaward limit of the District is the intersection line of the foreslope of the dune and backbeach. It is a zone in which natural processes are allowed complete freedom to operate. As a result, any cultural development in that zone should be prohibited. Dune building, either natural or artificial, should be encouraged. Existing dunes should in no way be lowered or narrowed artificially. Existing structures, including housing and supporting infrastructure, should be allowed to remain, although once they are destroyed beyond a certain extent, they should be condemned. Expansion of existing structures should be prohibited in the District, but minor repairs may be allowed.

Details about the management strategies are presented in this report in the form of policies to be adopted at state level by the Department of Environmental Protection and in the form of a model municipal dune ordinance. The adoption of both the policies and the ordinance will allow the dune zone to be managed in a manner that will provide protection to areas in the lee of the dunes, and that will enhance the value of the beach/dune system. However, management of the coastal zone should not stop at the dune zone. The barrier island as a whole interacts with the beach and the dune. Consequently, management practices should also be directed toward the areas not included in the Dune Management District. These strategies should not exclude development, but they should control it in such a way as to minimize interference with coastal processes. These management techniques would reduce the expenditure of public funds on erosion control. Allowing natural processes to function unimpeded will result in the development of natural beach/dune systems which will enhance the recreational resources of the New Jersey shoreline.

Section 1 - Introduction

1.1 General

There is increasing public concern about the quality of the New Jersey shore zone. At the Governor's Conference on the Future of the New Jersey Shore held in September, 1979, government representatives, public interest groups, and local citizens called attention to the need to protect the coastal system and conserve those characteristics that presently exist. The natural concern with shoreline erosion and damage to housing and utilities evokes a quest for information pertaining to the prevention of these losses. Along developed shorelines, there is an inherent conflict between humans and the sea. A rising sea level, coupled with attempts by people to maintain a static shoreline position in many areas, has gradually led to the removal of beaches and dunes. Cultural activities in the dune environment have been both constructive and destructive. In the past, the wholesale destruction of existing dunes to suit the interests of shorefront residents and visitors was commonplace. As a result, many buildings are now located where the protective dune would be. In the course of construction, it has been forgotten that the coastal dune indeed performed a function, and the loss of this function has consequences that may be undesirable. The dune serves as a barrier to storm penetration, and that function offers protection to all facilities located to its lee. On the barrier islands, some of which are quite narrow, the dune provides added protection against island breaching and inlet formation.

The inherent conflicts in the coastal zone require resolution through careful management and adequate knowledge of basic processes. One objective of sound management is to direct private development and thereby reduce private losses on barrier islands. This objective may be accomplished through phased, long-term relocation of housing and support services in response to the steady retreat of the shoreline. At present, building practices and resource uses which minimize interference with the natural processes must be implemented. One land use control process directed toward this objective is presented in this report. It is based on scientific theory and is designed to be used as a legal construct. The regulation of barrier island development is accomplished through the creation of a Dune Management District in which land use controls are implemented. The use restrictions discussed hereafter are focused on managing the dune environment because of the natural protection that dunes provide to buildings to their lee and because of their interaction with the beach.

1.2 Rationale for Dune Management

In the case of shorelines, the development of management options is constrained by several facts:

1) Most of the world's shorelines are characterized by negative sediment budgets and are continually eroding, although subject to short-term reversals.

2) The barrier island system prevalent along our Atlantic and Gulf seaboard is slowly migrating inland as a result of washover processes.

3) The amount of sand required to create a balanced sediment budget is awesome. The best source for large quantities of sand is the offshore zone. High costs and environmental constraints may preclude mining the offshore except in special cases.

Beach management is now at a point where static engineering projects have been attempted and found to be less than successful in reversing the long-term erosional trend. Current research has shown that traditional approaches to shoreline management, such as groins and seawalls, do not augment the sediment budget and thus do not create new beach materials and enlarge the beaches (CERC, 1977). While the engineering structures provide protection and maintain a fixed shoreline position, the beach continues to erode as a result of the natural processes which are operative. The result is a gradually narrowing beach which loses its potential as a recreation resource.

One alternative to engineering solutions is beach nourishment. However, the cost of moving great quantities of sand to the beach may be prohibitive. For example, at Miami Beach (FL), 10.5 miles of shoreline are being replenished with sand that is mined offshore. The estimated cost of this program is 64 million dollars (*Time*, 1979).

At present, there is increased pressure to develop broad shoreline management plans as called for in the Federal Coastal Zone Management program. In this context, the Governor's Conference on the Future of the New Jersey Shore established that the objective for the management of the coastal zone was to provide a balance between optimal usage of the resource and preservation for future use.

There is increasing awareness that the coastal dunes are an important component of the shore system, and there are many concerns expressed over the maintenance of the integrity of the integrated coastal dune and beach system (Godfrey, 1976; Leatherman, 1976). Certainly, the dunes are part of the beach/dune sediment system, and some effort to control development and to allow for dune migration would assist in maintaining the system. The dune zone is considered to be the appropriate area for exercising management principles and tools. Obviously, dune management is tied to the processes of dune development, and management, therefore, requires an understanding of how choices of land use interact with the events that sustain dunes. Just as obvious is the opportunity for morphologic research to establish the bases of management in and adjacent to the dune zone.

In order to preserve the area for future use, the beach/dune system and its management must be incorporated as an essential element of the coastal zone (Nordstrom, et al., 1978). One way of achieving this objective is through the creation of Dune Management Districts. The Dune Management District is a legal construct required for protection and enhancement of the dunes. The width of the District is essentially determined by examining the processes which affect dune formation and migration.

1.3 Dune Processes

Dune formation and migration depends on the transfer of sediment between beach and dune systems. Research has indicated that several factors influence the movement of sediment (Godfrey, 1977; Leatherman, 1976; Goldsmith, 1973). Three principal factors may be identified: 1) wind; 2) waves; and 3) vegetation.

1.3.1 Wind

Sand movement by wind is dependent on wind speed, direction, and duration. Research on the effect of wind speed on sediment transport indicates that sand grains begin to move when the wind velocity reaches a certain threshold level (Bagnold, 1954; Belly, 1964). The threshold level, however, varies with the size of the sediment because larger amounts of energy are required to move larger sediment particles. Bagnold (1954) suggests that the basic threshold value for the initiation of sand movement by wind is approximately 14 feet per second, or about 10 miles per hour.

As wind velocity increases, so does the capability of the wind to transport material. However, the total amount of sediment moved depends not only on wind velocity but also on wind duration. Thus, if average annual wind velocities for New Jersey (Figure 1-1) are compared, the effects of wind velocity and wind duration can be demonstrated. At Sandy Hook, northwesterly winds have an average velocity of 16.1 miles per hour, whereas the mean speed of the southwesterlies is 12.8 miles per hour. However, the southwesterly winds prevail for a greater amount of time than do northwesterlies (20% of the time versus 15%). It is, therefore, conceivable that the southwest winds transport as much sediment as do northwesterlies because of greater duration. On a day-to-day basis, this relationship is modified because the threshold velocity may not be attained on some occasions. In the example, it is probable that this situation applies mainly to the southwesterly winds which occur from spring to fall.

In evaluating aeolian sand transport, wind direction is another factor which should be considered because this determines where the sediment will be moved. Looking again at sample New Jersey wind data (Figure 1-1), it is possible to identify three quadrants of high mean wind velocity: 1) the northeast; 2) north; and 3) northwest. However, in terms of duration, the three most important quadrants are the northwest, west, and southwest. New Jersey beaches are generally oriented in a north-south fashion. This analysis, therefore, indicates that net sediment transport by wind should be in an offshore direction. Only northeast winds appear to have a high enough velocity and duration to produce an onshore movement of sediment. Of course, the effects of the direction component will be modified at specific coastal sites which differ significantly from the general north-south orientation.

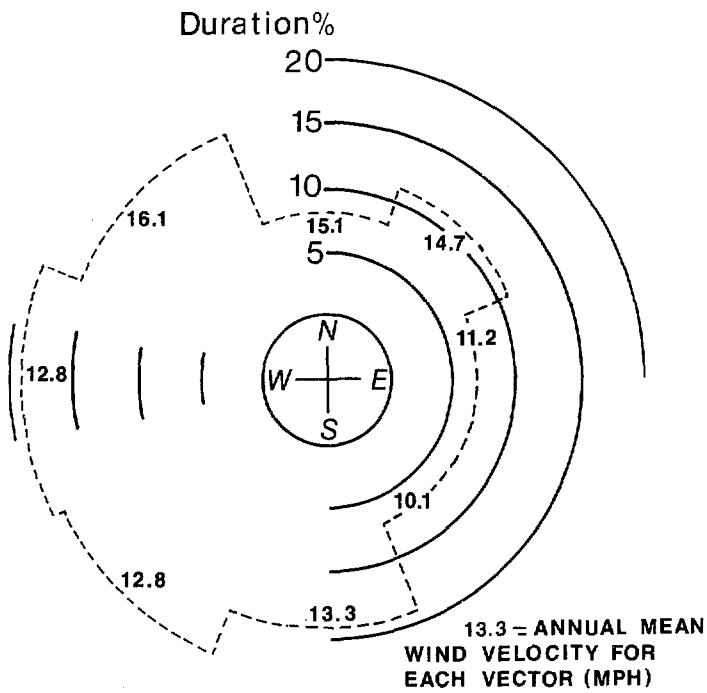


Figure 1-1. Wind rose for Sandy Hook, New Jersey.

The intuitive correlations between wind speed, duration, and direction have been empirically studied in Canada (Rosen, 1979), Virginia (Leatherman, 1976), and North Carolina (Dolan and Godfrey, 1973). Although they have not been studied in New Jersey, it appears highly probable that these same relationships exist in this state. However, a factor which could modify the effects of wind as a means of sediment transport is the highly developed nature of the New Jersey shoreline. Few studies have examined how an artificially maintained dune or buildings may modify the natural relationships. This modification should be an important part of future dune research.

1.3.2 Waves

Under storm conditions (onshore winds) short, steep, erosional waves will move sand from the beach face to the longshore bar and the seaward portion of the dune will be attacked (Figure 1-2). This results in a loss of dune sediment. Under such conditions, raised water levels and increased breaker heights may cause overwash to occur which can deliver sizeable quantities of sand from the beach environment to the lee of the dune crest (Leatherman, 1976; Leatherman, Williams, and Fisher, 1977). This sediment is deposited in the form of overwash fans which are considered to be simply temporary storage areas from which sediment is eventually redistributed by the wind (Fisher and Stauble, 1978).

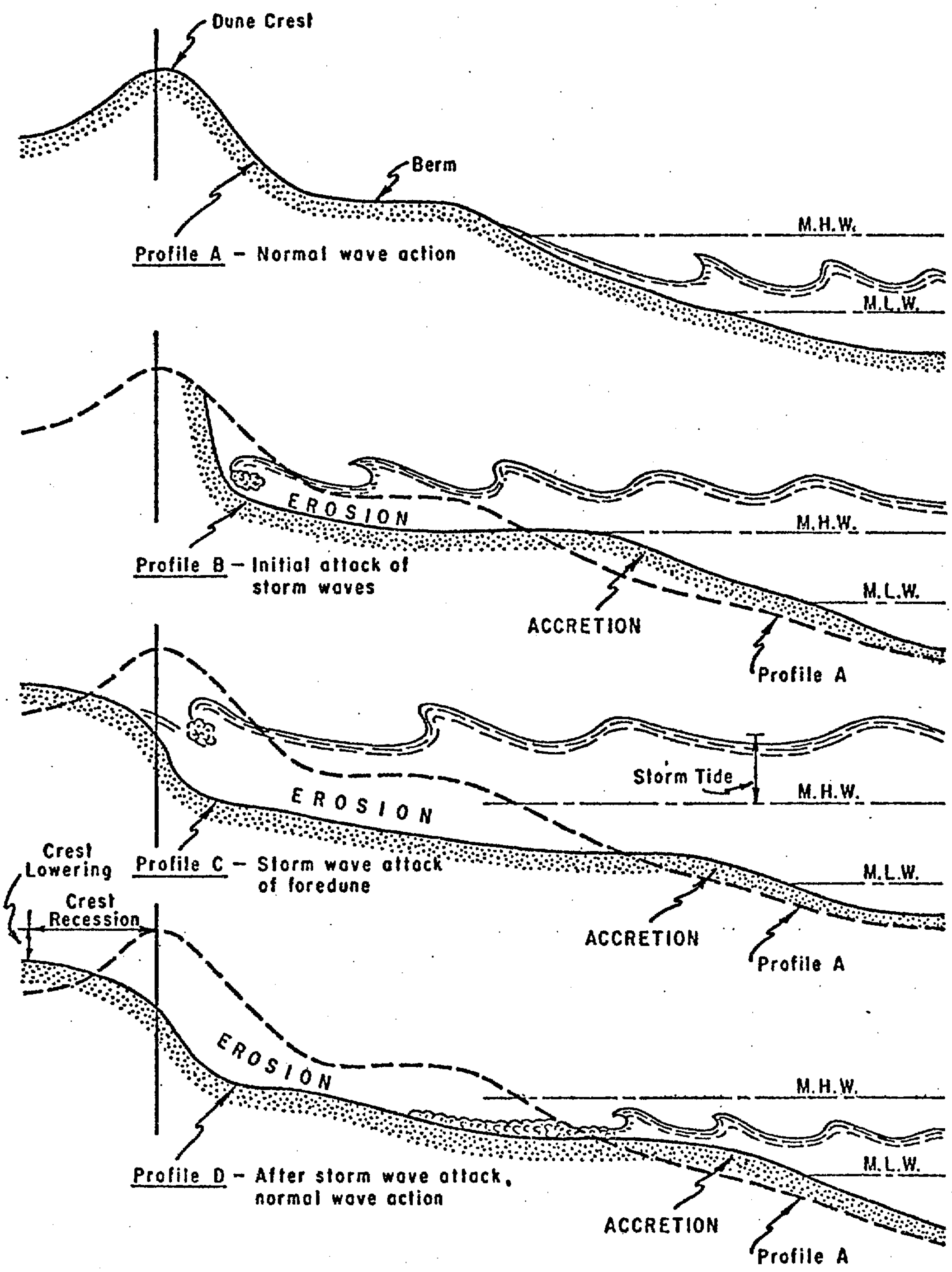


Figure 1-2. Schematic diagram of storm wave attack on beach and dune (from CERC, 1977).

Much of the sediment that was carried to the longshore bar by the high-energy storm will be returned to the beach by post-storm, flat, low-energy waves. There is generally a loss of sand from the beach by longshore transport to downdrift beaches and by bottom currents to the offshore. These loses are partially compensated for by the addition to the beach of sediments derived from updrift areas.

If a sediment budget approach is utilized in which inputs, outputs, and storage are balanced against each other, it is frequently found that sediment loses are not totally replaced by the inputs. In this case, the budget is said to be operating at a deficit. The deficit may be particularly severe if sediment transport from updrift beaches is intercepted by groins or jetties. The result of a deficit or negative sediment budget is beach erosion, dune scarping, and eventually, overwash. The inland transport of sediment represents the storage element of the budget. The net result of these processes is the migration of the barrier island system in much the same overall form. This sequence of events is taking place on most of the undeveloped barrier islands of the east coast which are presently experiencing a negative sediment budget.

1.3.3 Vegetation

Vegetation is important in providing a baffle against wind and in holding the unconsolidated sand grains in place. The former favors dune growth at the margin of the vegetation, whereas the latter contributes to stabilization of the surface of the dune. The vigor of the vegetation is important. Dense stands of vegetation may impose a complete barrier to aeolian transport. Vigor depends upon nutrients, disease, parasites, human disturbance, and other stresses which are associated with daily fluctuations in weather. The species are important as well. Some plants, such as dune grass, although effective in trapping sand, do not completely bar sand transport as do some of the woody shrubs or vines, such as poison ivy. The species prevalent will be determined by climate, tolerance to salt spray, and succession. The amount of salt spray is a local phenomenon strongly affected by broader regional controls (wave conditions, frequency of overwash, and the form of the dune itself). High, wide dunes protect the vegetation on the landward side of the dune from both flooding and salt spray, and woody shrubs will probably predominate. Low, hummocky dunes will allow salt spray to penetrate inland, and the vegetation will be restricted to salt tolerant grasses (Nordstrom and Psuty, 1978).

1.3.4 Dune Formation Models

Using the information presented above, dune formation models have been developed for the New Jersey coastline. The situations represented here apply particularly to natural undeveloped barrier island systems. On populated coastlines where dune systems are stabilized through the use of fences and/or vegetation, the described sequence of events may not apply. It is possible that if it penetrates to the backdune area, sediment may become trapped there and be of little use in dune formation. However, since information pertaining to sand transport in a populated dune zone is largely lacking, the dune formation models developed elsewhere for natural shorelines are used to conceptualize dune formation processes in New Jersey.

In New Jersey, storm conditions produce onshore winds (northeasterlies and easterlies) and associated high waves and storm surge.

The onshore response is shown in Figure 1-3. Depending on conditions, water may: 1) flow up to the dune scarp, eroding material from the beach and the dune, and carrying it to the nearshore; 2) flow up to and over the dune scarp, eroding material from the beach and the dune, and depositing it just over the dune crest; and 3) flow through low points in the dune, eroding material from the beach and the throat, and depositing it in an overwash fan.

The effect of the wind varies as the storm progresses. Initially, while the sand is still dry, wind removes sediment from the beach and the non-vegetated dune crest, carrying it to areas just behind the crest. Vegetation plays an important role here by preventing erosion in some places and causing deposition in others. After the storm has progressed for a time, if precipitation has occurred, sand transport will be diminished due to the bonding of sand particles by water.

In the post-storm/offshore wind model (Figure 1-4), the wind is the dominant process and the role of water is negligible. The dominant winds (northwesterlies and westerlies) move sand from the washover fans to the areas to the lee of the dune crest, accumulating where vegetation causes a decrease of wind velocity and consequent deposition. Some of the washover sediment may be carried backward through the throat and deposited on the beach or even in the nearshore area. Wind also erodes sediment from the non-vegetated dune crest and deposits it seaward of the dune scarp, on the beach, or in the nearshore area. Finally, wind removes sediment from the beach face and carries it to the nearshore.

The role of waves in the post-storm sequence is limited to removing sediment from the longshore bar which built during the storm. This sediment is transported to the beach where it is deposited in the form of a berm. Sand from the berm may then move inland during a storm sequence as described above.

These models are useful for conceptualizing the relationships between natural dune processes and their natural responses. It is important to recognize that these processes must be given space in which they can be active. The presence of buildings and roadways certainly modifies the models. However, the manner in which the natural system is modified must be thoroughly researched.

1.4 New Jersey Dunes

One objective of this study is to examine New Jersey dunes in order to obtain data on the spatial variations in dune height and width characteristics throughout the state. These dimensions are considered to be the most important dune characteristics in terms of protection and sediment budget. A classification of New Jersey dunes was formulated and mapped to allow the display of the information. Data were obtained by examining aerial photographs and by carrying out beach surveys. The location of the profile lines was determined by examining the aerial photographs and selecting general areas where profiles should be taken. Because the profile lines had

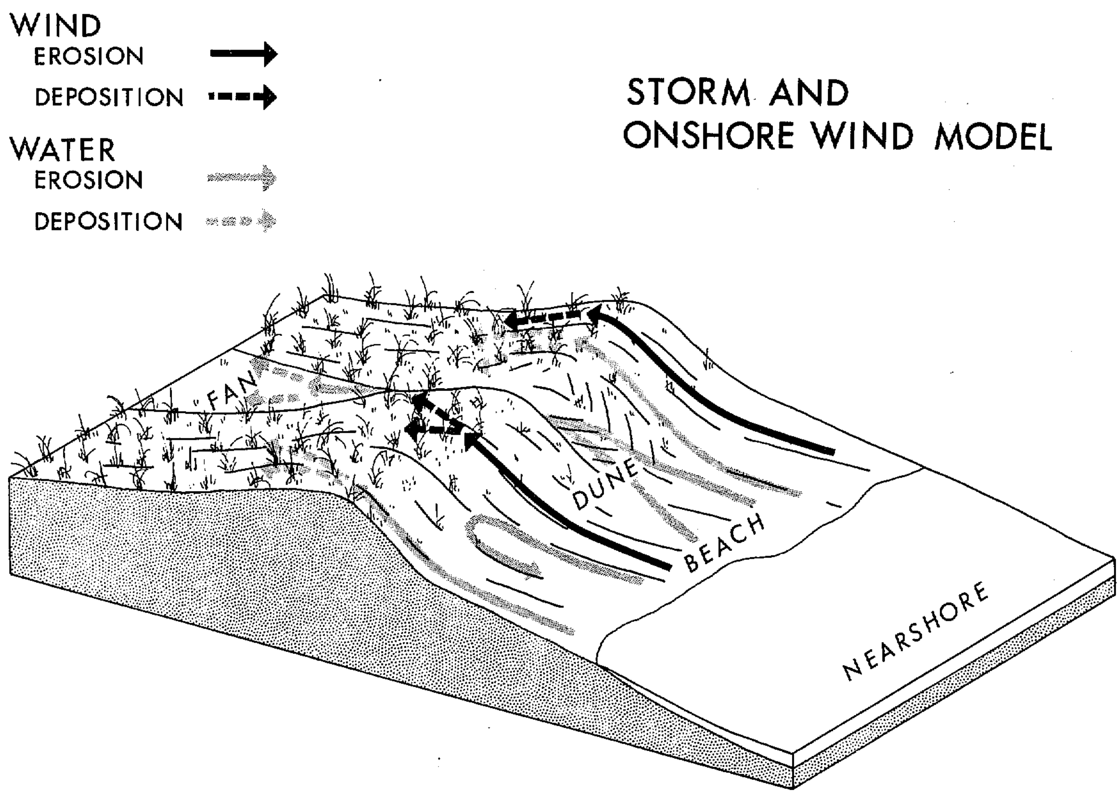


Figure 1-3. Dune formation processes during an onshore wind period.

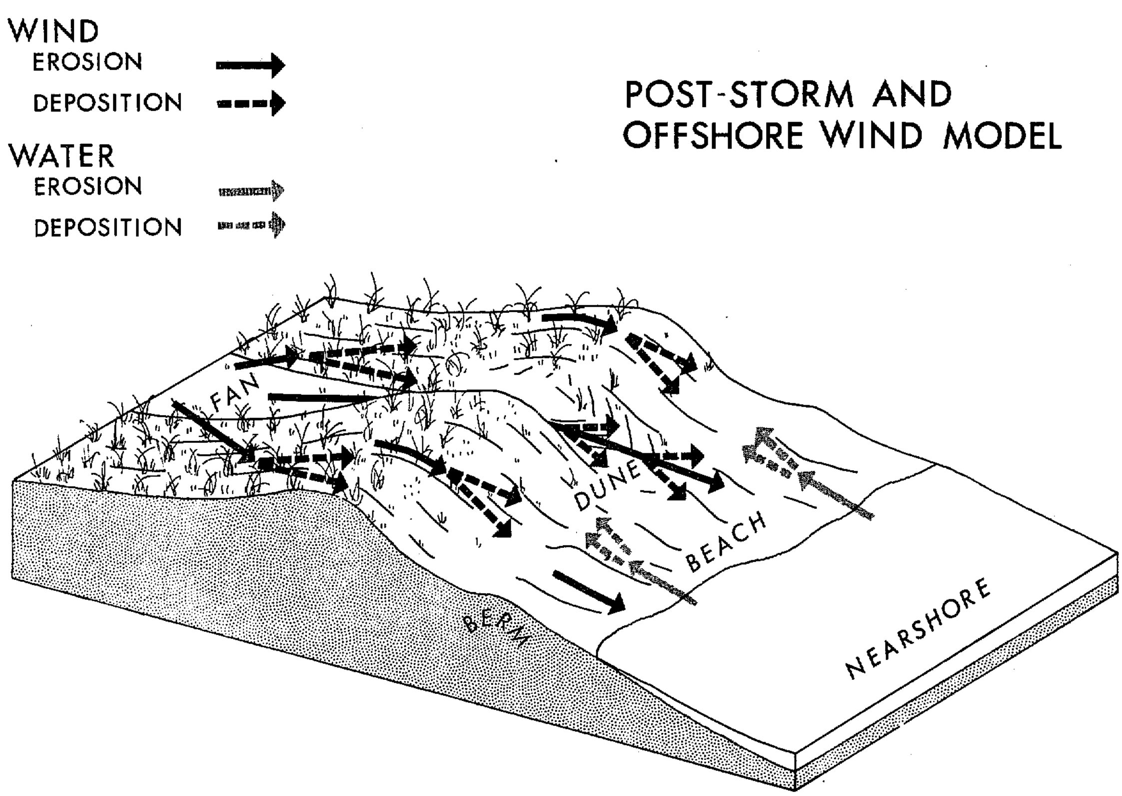


Figure 1-4. Dune formation processes during an offshore wind period.

to be tied to sea level datum, their specific location depended on the location of existing bench marks. Profile lines were, thus, established with the objective of keeping the distance between the bench mark and the profile sub-datum at a minimum.

Sixty-three sites were identified at which beach surveys were conducted. The sites of the profile lines are identified in Plate I. Appendix A lists the specific locations of these profiles with respect to known markers so that they may continue to be used in future beach studies.

Once the data obtained from the surveys were reduced and plotted on graph paper, dune height and width characteristics were computed. Basic height and width categories were identified, and using the profile information, shoreline segments with similar height or width characteristics are identified (Figure 1-5). This classification of New Jersey dunes is also represented in greater detail on Plate I.

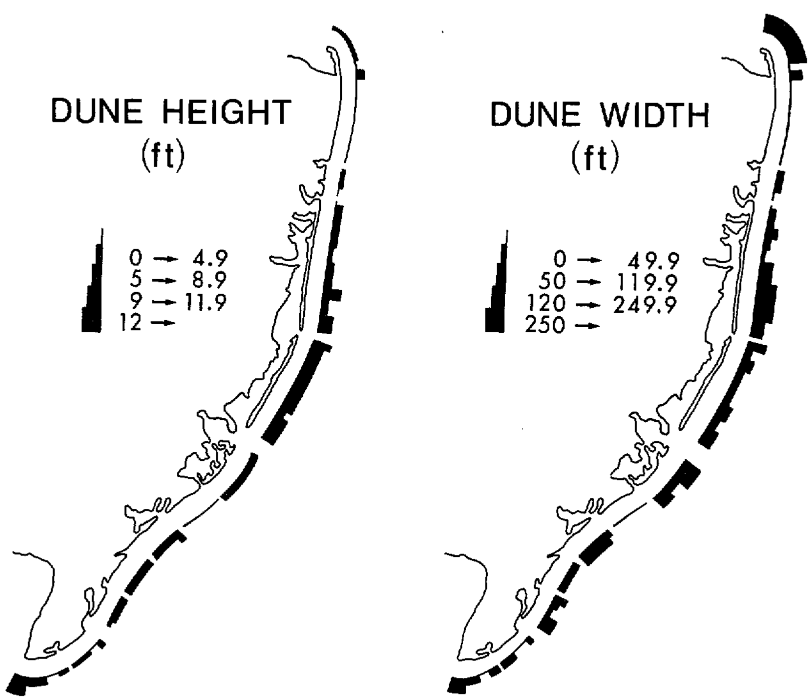


Figure 1-5. Height and width ranges of New Jersey dunes.

Another objective of this part of the study was to determine where dunes are present and where they are absent. This was accomplished by examining aerial photographs. The localities where dunes are absent are also identified on Plate I. Dunes are absent from the boundary of the Sandy Hook Unit of Gateway National Recreation Area south to the vicinity of Sea Girt. Dunes are also absent at certain localities north of Island Beach State Park, in particular in the vicinity of Lavalette, and along the shoreline at Atlantic

City, at Ocean City, at Wildwood, and Cape May. Many of these locations must be considered as special problems because existing shore protection structures are likely to prevent future dune formation. At some locations, however, such as at Lavalette, the dune has simply been bulldozed away, leaving a gently rising beach with no protective dune. The houses are located just behind the highest point of the profile, and there are no engineering structures present. The profile is sufficiently wide to allow for the construction of a protective dune if one were required. Areas where dunes are absent along the shoreline may thus be divided into two categories: 1) areas backed by seawalls or bulkheads where there is little potential for natural dune formation without removal of the engineering structures; and 2) areas with no dunes and no engineering structures where dunes could develop naturally if current building practices were changed. When dune management areas are created, these characteristics will need to be accounted for. Heavily developed areas with no existing dunes such as Atlantic City will necessarily have to be considered differently than areas where there exists some potential for dune formation.

Section 2 - Dune Management Areas

2.1 Principles for Dune Management Delineation

Whereas management practices along the shoreline have generally focused on the use of engineering structures, some attempts have been made to manage the beach/dune zone. In general, it is possible to identify two approaches that have been taken toward coastal dune management. The first is to allow the natural system to prevail. This is often practiced on undeveloped shorelines or areas where the principal land-use is recreation. Most other areas will attempt some sort of modification of the natural system. The modification may involve attempts at maintenance of coastal dunes. Examples may range from maintaining a dune position by bulldozing sand to a preferred location, to controlling access routes, to undertaking minor repairs of the dune crest, or to posting signs to keep people from walking on the dune.

The concept of maintaining a coastal dune usually has meant preserving or stabilizing a dune line at a designated location, and frequently the dune position is considered to be unrelated to events on the beach. The consequences of this approach have been identified in reports on the Outer Banks of North Carolina (Dolan et al., 1973; Godfrey and Godfrey, 1973). These studies compared two stretches of barrier islands in North Carolina. One was stabilized in the 1930's by the Corps of Engineers, the other remained natural. On the natural beach, the high wave energy is dissipated on the wide beach, though storm conditions occasionally cause erosion of the dunes and landward transport of sediment via overwash. The authors note that these processes in combination with a rising sea level produce a gradual inland migration of the entire barrier island. On the stabilized beach, in order to protect a road, dunes were built by installing sand fences and, once the dunes reached an adequate height, by planting grasses, shrubs, and trees. The most obvious difference between the two systems is that the stabilized beach is on the average five times narrower than the natural beach. As a result, on the stabilized beach the waves often reach the dunes and cause considerable erosion on the dune face. The longshore current carries away all the eroded sediment, and the dunes have no natural source of replenishment sediment. The dune is maintained in one position, but the beach will continue to narrow, and the dune will be scarped leading to the eventual destruction of the dune.

These same two systems were compared in terms of response to the effects of a hurricane (Dolan and Godfrey, 1973). This study provided some of the first quantitative estimates of dune building by wind and water. At each beach, pre- and post-storm profiles were compared. At the natural beach, the summer berm was removed, and the beach crest retreated a distance of 120 feet. However, nine days later a new berm had already begun to form. The authors reported that some of the material eroded from the berm was carried inland by overwash, but the dunes were considered not to have suffered great damage. Following the storm, southerly winds were observed to have carried overwash sediment back to the dunes.

At the stabilized beach, sediment was removed from the beach and from the dune face causing a linear retreat of 9 to 15 feet. However, the authors observed that no recovery could be documented a full year after the storm. The important conclusions are that the natural system works better than the stabilized one. In the natural system, a wide beach allows the gradual dissipation of wave energy. The low dunes control storm surge while allowing material to pass through to the backdune area. This sediment is a source of replenishment for eroded dunes. The authors emphasize overall that dunes are an integral part of the natural system.

The sediment budgets that exist along our shorelines at this time make it unrealistic to approach dune and beach management as long-term stabilization along a line. The system is generally operating with a negative sediment budget,and the entire system is being displaced inland. The relationship of a dune to the beach, dune zone, and dune district on an eroding barrier island is shown here diagramatically (Figure 2-1). Modification of the dune by humans usually includes bulldozing to facilitate construction and to provide a view of the sea and paving over the landward side of the dune (Figure 2-1, Time 2). The result has been a lowering of the land surface. Although the dune has been severely restricted, there is no change in the horizontal dimensions of the dune zone which represents the width of the dune under natural conditions (Nordstrom and Psuty, 1978).

The configuration of the barrier island changes with time (Figure 2-1, Time 3). Attempts by humans to maintain a fixed position in face of a rising sea level and continued erosion through longshore and off-shore transport have resulted in a narrowing of the beach and dune zone. Some protection from storm flooding is gained by artificially increasing dune height through the use of dune grass planting and sand fencing. The new dune is high enough to provide adequate protection against flooding, but the width must be increased to provide an adequate reservoir of sand to compensate for beach erosion.

It may be noted here that the natural rate of shoreline retreat may be delayed by manipulating the sediment budget. This concept calls for the continuing replenishment of the beach/dune system. While it has been demonstrated that massive beach nourishment programs designed to stabilize the shoreline in one place are prohibitively expensive, smaller scale maintenance programs might be implemented. The infusion of sediment associated with nourishment will cause a temporary change in the sediment budget. However, it must be understood that the new sediment is buying time. Beach nourishment projects

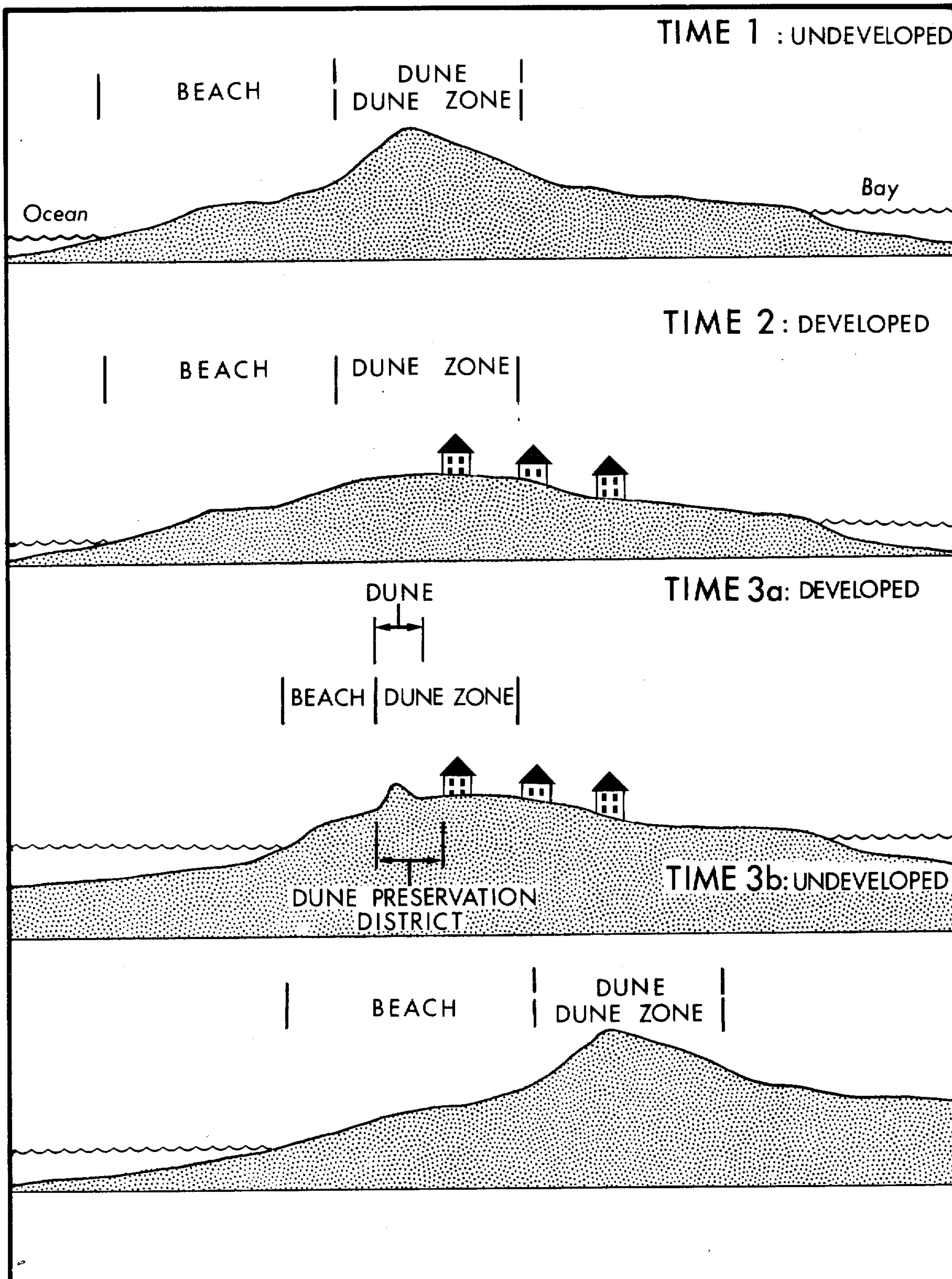


Figure 2-1. The relationship of the beach and dune to the dune zone and the dune district under different conditions of shoreline development and during different periods of time (from Nordstrom, et al., 1978).

must be implemented at regular intervals in order to offset the loss of beach sediment. If such a program is halted, a negative sediment budget will exist again, and shore retreat should be expected.

If no development had taken place, natural processes would cause the retreat of the barrier island (Figure 2-1, Time 3b). By contrast, in the case where development has taken place (Figure 2-1, Time 3a), a static shoreline position is maintained. This situation is incompatible with the natural processes. Key decisions must, therefore, be made regarding the manner in which development can be rendered compatible with natural processes.

Along most of the shoreline, it may be observed that all too often as local, state, and federal agencies attempt to manage the coastal system over which they have jurisdiction, the attention is directed at shoreline erosion, and the beach/dune system is neglected. The abuses are manifold. Frequently, the construction is too close to the shoreline and, in the process, the dunes are completely leveled to facilitate construction and access to the beach. In other cases, the vegetation cover is completely destroyed with the immediate result that the natural dunes which were once anchored by plant development are leveled by natural processes. Yet, another example of the degree to which man continues to abuse the system is where a developer decides to bulldoze the dune seaward and erect a structure behind it. The dune ridge, unstable in its new location, frequently disappears in a very short time.

The replacement of dunes by structures emphasizes the basis for concern in dune management. Modifications of the dune which occur as a result of construction along the shoreline causes the dune to no longer occupy its position in the natural system. However, the dune performed a function in its former position, and the loss of this function has consequences that are undesirable. Dunes serve as a barrier to storm penetration, and that function offers protection to all facilities located to its lee. Further, the dune is a sediment reservoir that can interact with the dynamics on the beach. As the reservoir contributes sand to buffer beach erosion or to store sand for future release, it is part of the total beach profile. The loss of the dune is also the loss of sand volume from the beach profile, and in the concept of a sediment budget in the beach zone, the removal of the dune will result in a greater inland displacement of the beach profile.

On the basis of this discussion, as Dune Management Districts are created, it is possible to identify several basic principles which need to be observed:

1) The beach and the dunes together form the beach profile in which sediment is continually being exchanged between the two sub-units, and to treat one without recognition of the other is shortsighted.

2) Dunes provide for life safety and property protection during the elevation of storm water, they buffer rates of shoreline erosion.

3) It must be recognized that the beach/dune system is migrating and that any Dune Management District boundaries are assumed to be dynamic.

4) Because of the dynamic nature of the dune zone, Dune Management District boundaries should be reviewed at predetermined time-intervals, or following a catastrophic storm which significantly modifies the beach/dune system.

5) In order to be defensible in a court of law, a Dune Management District must be given absolute dimensions which are obtained through the use of scientific theory and empirical data.

6) Planning for development in or adjacent to the Dune Management District should accommodate natural shoreline migration by providing for development that is compatible with the natural processes.

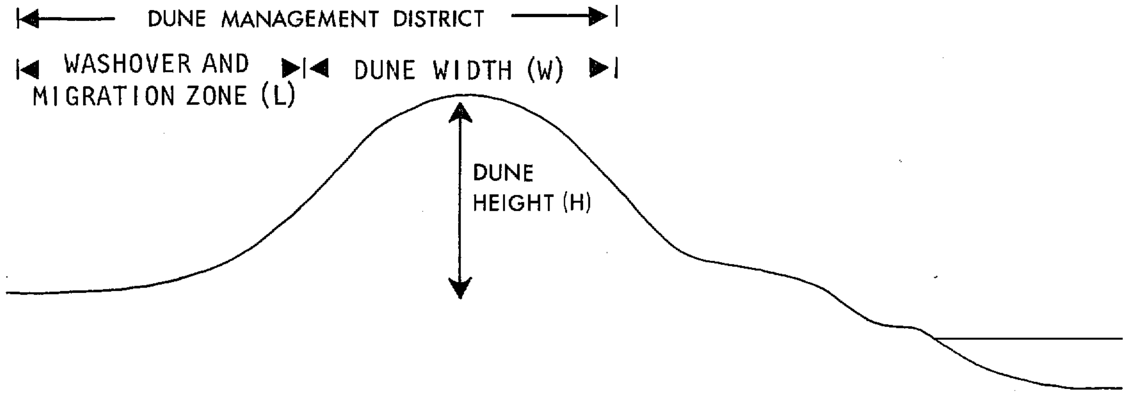
2.2 Dune Management Areas Delineation

The establishment of a Dune Management District is a component of the total concept of managing the beach/dune system. This concept has a theoretical base and guidelines for its implementation. Having demonstrated the rationale for implementating Dune Management Districts, attention must now be turned to the methodology required to give dimensions to the District. Specific measures of height, width, and setback (Figure 2-2) must be determined and incorporated as part of dune district legislation. Dune height will be established to provide some degree of protection. Height plus dune width describes the volume of sand to be incorporated in the sediment reservoir. The basis for this volume is the calculation of the beach budget during the design storm interval. There must be sufficient volume in the dune to contribute sediment to the beach to buffer erosion and still maintain its crest height. Further, there must be a distance to the lee of the dune crest into which the dune may migrate. The migration may be accommodated by a setback requirement that is related to the rate of displacement.

2.2.1 Height

Because the height component determines the extent to which inland areas may be flooded by ocean water, it is necessary to determine the magnitude of conditions that produce dune overtopping. The overtopping is essentially a function of storm surge and wave runup. Storm surge may be defined as "a rise above normal water level on the open coast due to the action of wind stress on the water surface" (CERC, 1977). Wave runup is simply the "rush of water up a beach on the breaking of a wave on the foreshore" (CERC, 1977). Runup is calculated as "the vertical height above stillwater level that the rush of water reaches" (CERC, 1977).

RATIONALE FOR DUNE MANAGEMENT DISTRICT



H → MINIMUM DUNE CREST ELEVATION TO PROVIDE PROTECTION AGAINST STORM SURGE

W → PROVIDES PROTECTION AGAINST STORM PENETRATION

HW → VOLUME OF SEDIMENT TO BUFFER EROSION FROM THE BEACH

L → UNDEVELOPED ZONE ALLOWS FOR WASHOVER DEPOSITION AND SEDIMENT TO LEE SIDE OF DUNE, ALLOWS FOR SLOW INLAND MIGRATION OF BEACH-DUNE SYSTEM

Figure 2-2. Factors considered in Dune Management District delineation.

The procedure for calculating runup is described in the *Shore Protection Manual* (CERC, 1977), but it applies to the design of engineered protection structures, such as seawalls or breakwaters. A sample calculation taken from that source is presented in Appendix B.

This same procedure is used to calculate runup on a beach/dune profile. For this project, design situations have been adopted in order to calculate runup values. Recognizing the geographical variation of the New Jersey shoreline, representative profiles from four different segments (Figure 2-3) were selected for use in the computation procedure. The design profiles were constructed by averaging the width and height characteristics of from four to eight empirical profiles available for each segment. The Segment 1 profile is based primarily on Sandy Hook data. The Segment 2 profile is computed from information collected at Seaside Park by CCES personnel during 1977-1978. Profiles for Segments 3 and 4 are based on data collected by Birkemeier (1979). The four design profiles are shown in Figure 2-4.

Principal components of the runup calculation procedure are the foreshore and nearshore slopes, beach width, deepwater wave height, wave period, and storm surge (Figure 2-5). The beach characteristics are obtained from the design profile. Storm surge, wave height, and wave period data were gathered at Atlantic City for a period of years. Frequency analyses of this information were reported by the U.S. Army Corps of Engineers (1976) and by Thompson (1977). All of this information is plotted on one graph (Figure 2-6) which presents storm

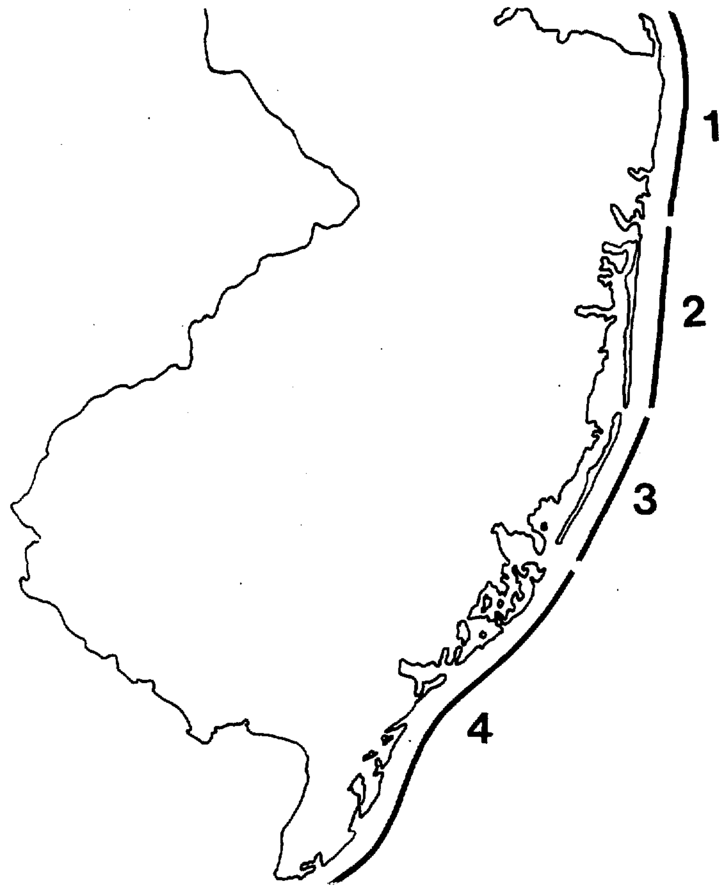


Figure 2-3. New Jersey shoreline segments utilized in this study.

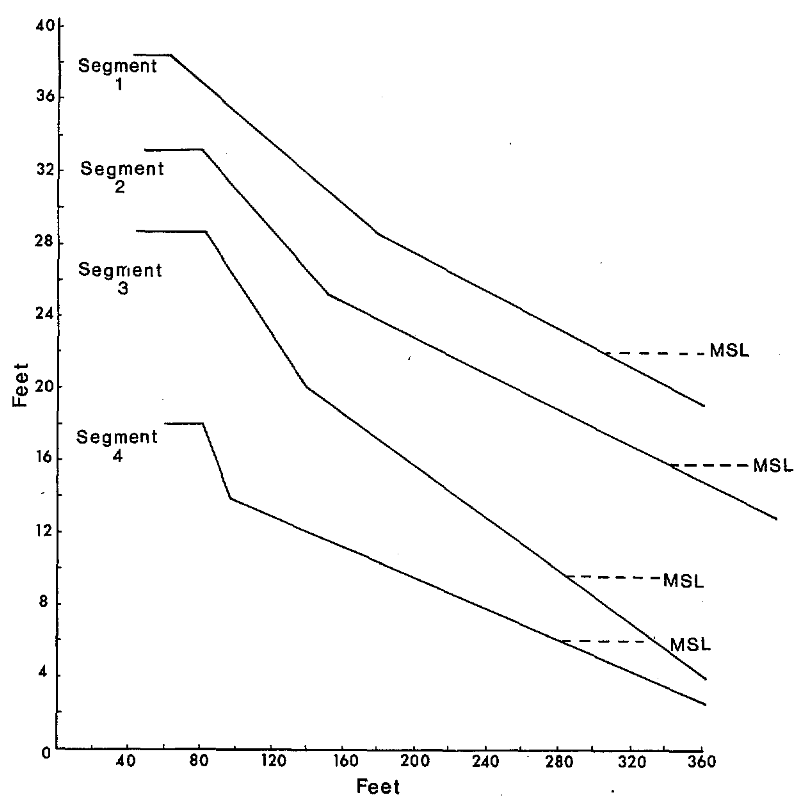


Figure 2-4. Design profiles utilized in runup calculations.

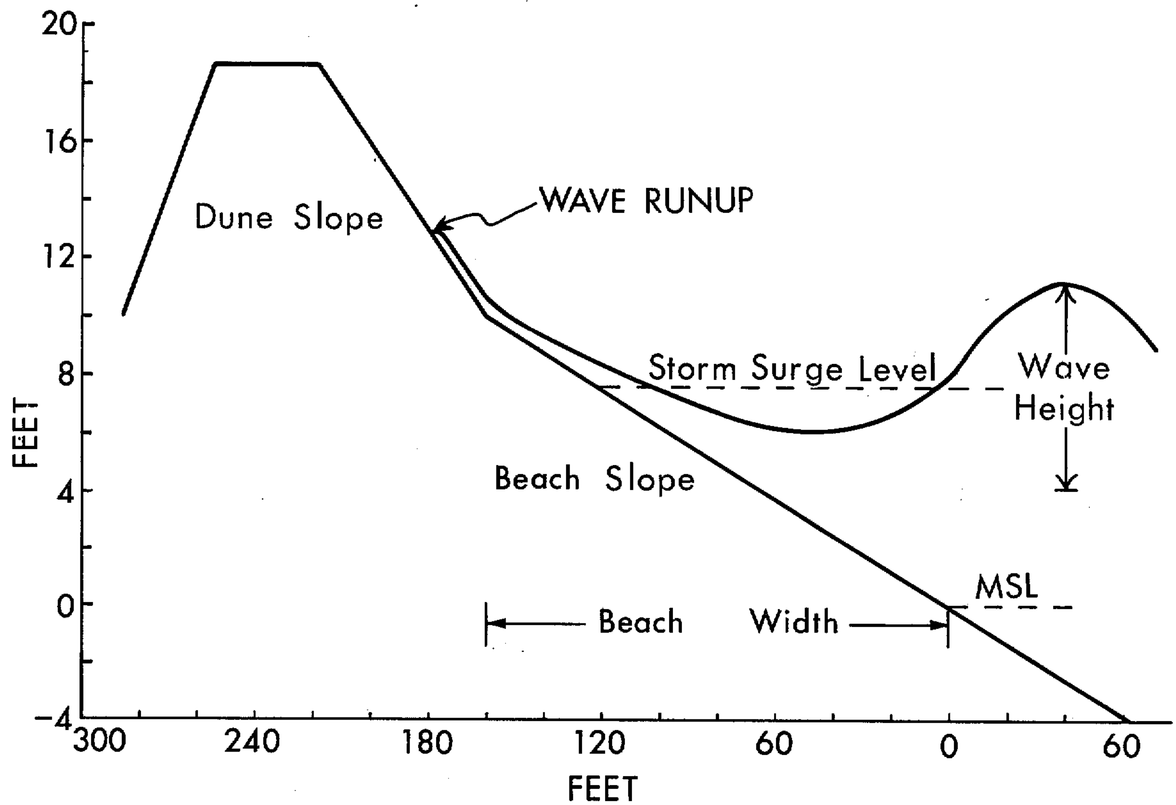


Figure 2-5. Components of the runup calculation procedure.

surge, wave height, and wave period in relation to predicted frequency of occurrence. While tidal and wave characteristics are certain to vary along the New Jersey shoreline, long-term data have only been collected at Atlantic City. Until better data sets become available for other stretches of the shoreline, the Atlantic City data must be considered to be representative of the entire New Jersey coast.

Data used on the runup calculations were obtained from the frequency analyses (Figure 2-6 and Table 2-1). An example of the calculations for Long Beach Island is presented in Appendix B. The runup values obtained for each of the selected frequencies are graphed for each of the four profiles (Figures 2-7 and 2-8). The runup elevations presented in these figures indicate only a minimum height above sea level required to prevent overtopping in a storm of a given frequency of occurrence. The runup elevation is not identical to dune height. Dune height is the difference between the highest point on the profile and the maximum beach elevation. In order to determine the minimum dune height required to prevent overtopping in a storm of a given frequency of occurrence, the design backbeach height is subtracted from the predicted runup. The dune height required to prevent overtopping in a given storm may then also be predicted from Figures 2-7 and 2-8 in which dune height is represented on the right y-axis.

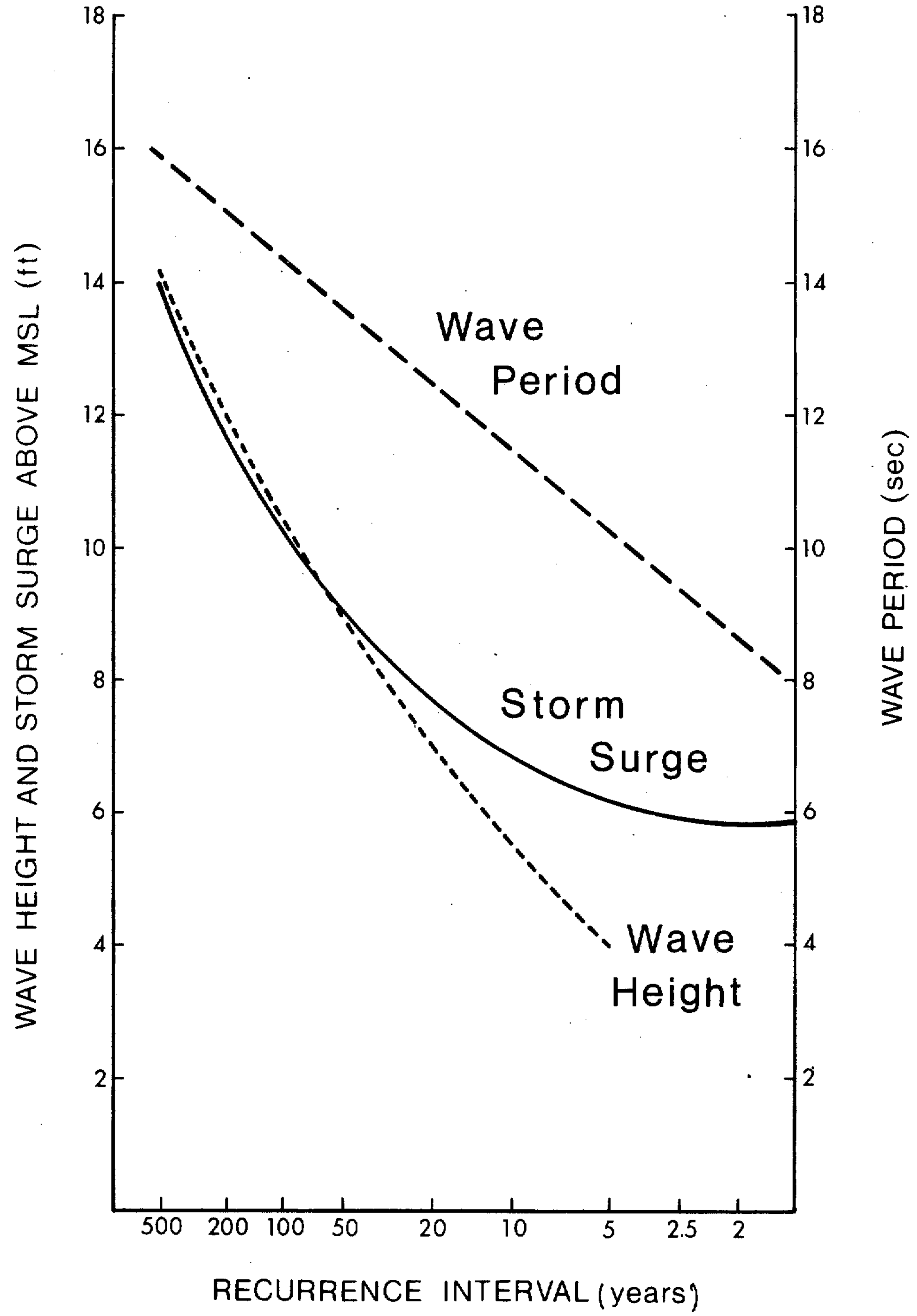


Figure 2-6. Wave and storm surge information used in runup calculations (Source: U.S. Army Corps of Engineers, 1976 and Thompson, 1977).

Runup varies from shoreline segment to shoreline segment (Figures 2-9 to 2-12) as a result of different design profiles for each of the four segments. For Segment 1 (Figure 2-9), a storm with a 20 year recurrence interval produces a runup of 12.2 feet, whereas a storm of an 83 year recurrence interval overtops the dune. In Segment 2 (Figure 2-10), the same 20 year storm has a runup of 11.5 feet. The dune on this profile will be overtopped by a 110 year

Table 2-1. Design specifications for runup calculations (Source: U.S. Army Corps of Engineers, 1976 and Thompson, 1977).

Storm probability	50%	25%	20%	10%	5%	3%	2%	1%	0.5%	0.2%
Surge (ds) (feet)	5.7	6.1	6.3	6.9	7.8	8.2	8.9	10.1	11.6	14
Wave Height (H) (feet)	-	-	4	5.6	7	8.2	9.1	10.6	12.1	14.1
Wave Period (T) (sec)	8	9.7	10.2	11.2	12.4	13.1	13.6	14.2	14.9	15.6

storm. In Segment 3 (Figure 2-11), the predicted runup for a 20 year storm is 12.9, and a storm with a 77 year recurrence interval will overtop the dune. Finally, at Segment 4 (Figure 2-12), characterized by the flattest beach of the four, a 20 year storm produces a 10.8 foot runup, and the dune is overtopped by a 40 year storm.

2.2.2 Width

The spatial variation in runup which exists along the shoreline needs to be accounted for in the determination of the width of the Dune Management District. It is necessary to relate the dune heights as obtained from the runup values to dune width. It was hoped that a storm frequency analysis like that for runup would be possible in order to determine required dune widths. If erosion rates associated with individual storms could be predicted, it would be possible to infer dune width requirements from the erosion rates. However, an examination of the available models (Edelman, 1969; Vallianos, 1974) for predicting erosion rates associated with individual storms indicated that these models are still too crude to permit reliable prediction. Therefore, another methodology was required.

Using the concept of dynamic equilibrium, it seems reasonable that dunes of given heights must also have an equilibrium width based in part on the foreslope and backslope of the dune. Ideally, then, this would be an appropriate approach to determining dune width. However, there is a lack of information about the equilibrium dimensions of dunes. In fact, an equilibrium form may be difficult to identify in nature. Field work done in natural areas reveal that dunes of the same height have different widths, and there appears to be no definitive correlation between the two variables. Research on the construction of artificial dunes indicates that dunes may be built to almost any desired height or width (CERC, 1977).

For this report, it was decided that an appropriate way of approaching the problem would be to examine New Jersey dunes and to correlate height and width using regression. Dune heights and widths

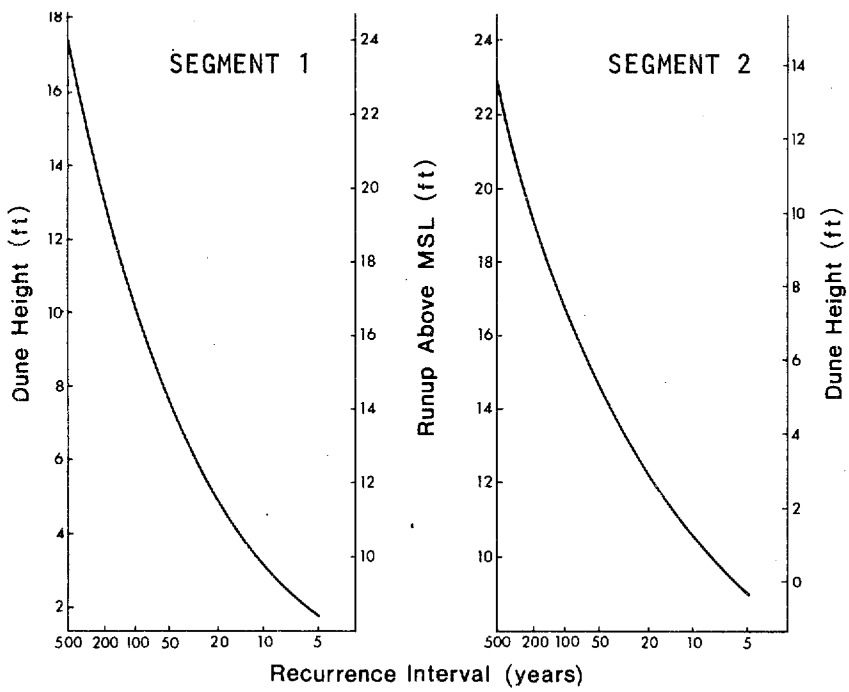


Figure 2-7. Runup predictions curves for Segment 1 (left) and Segment 2 (right).

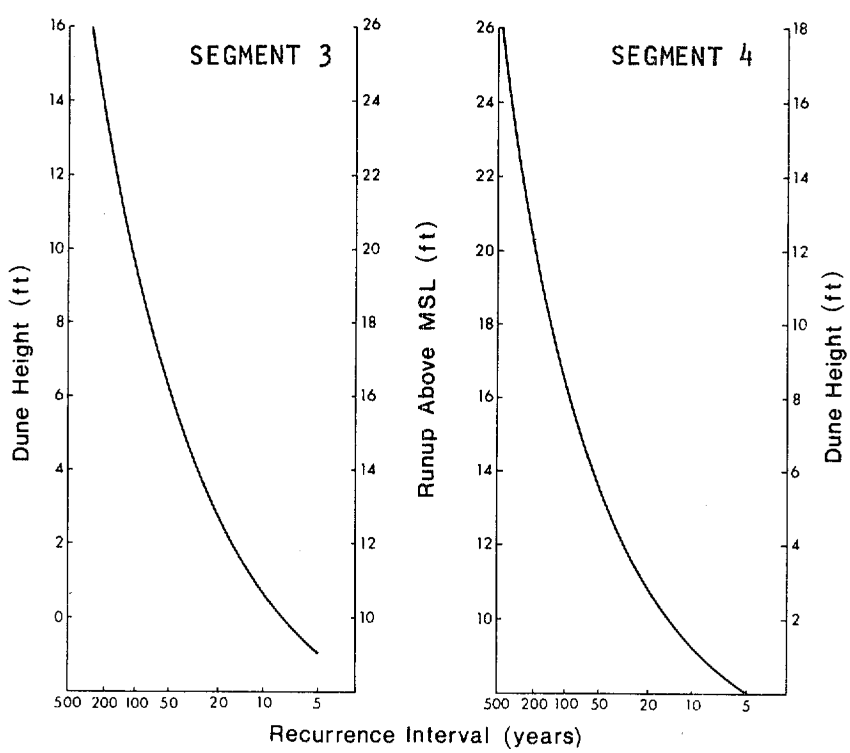


Figure 2-8. Runup prediction curves for Segment 3 (left) and Segment 4 (right).

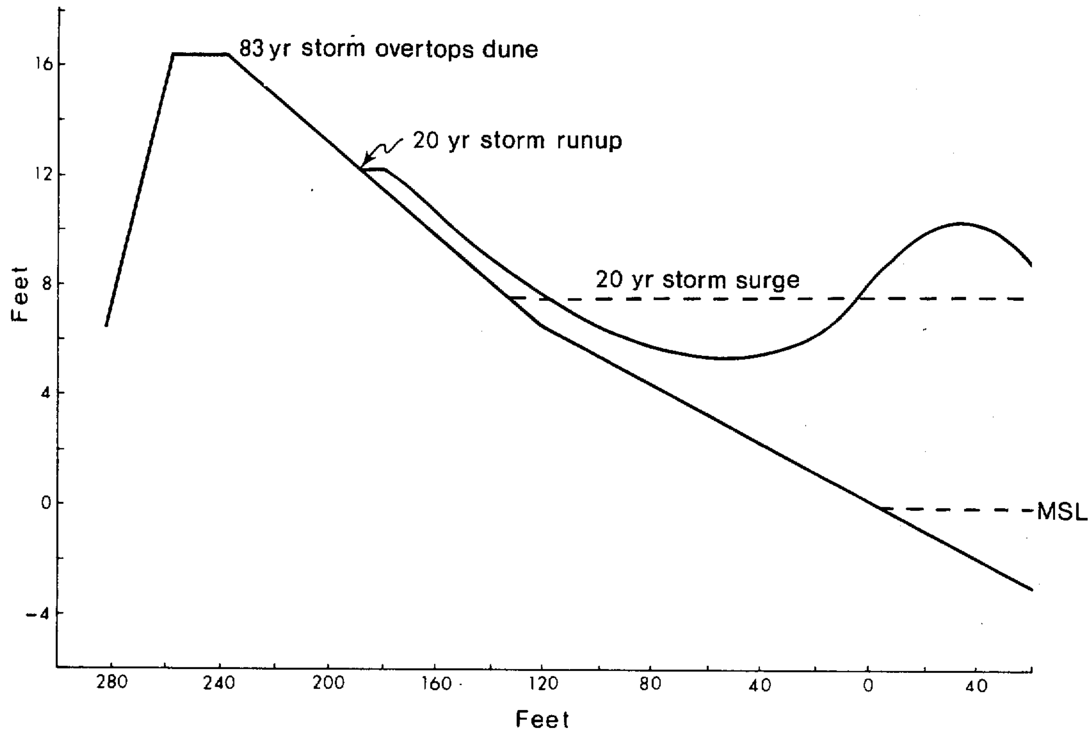


Figure 2-9. Predicted runup on Segment 1 design profile.

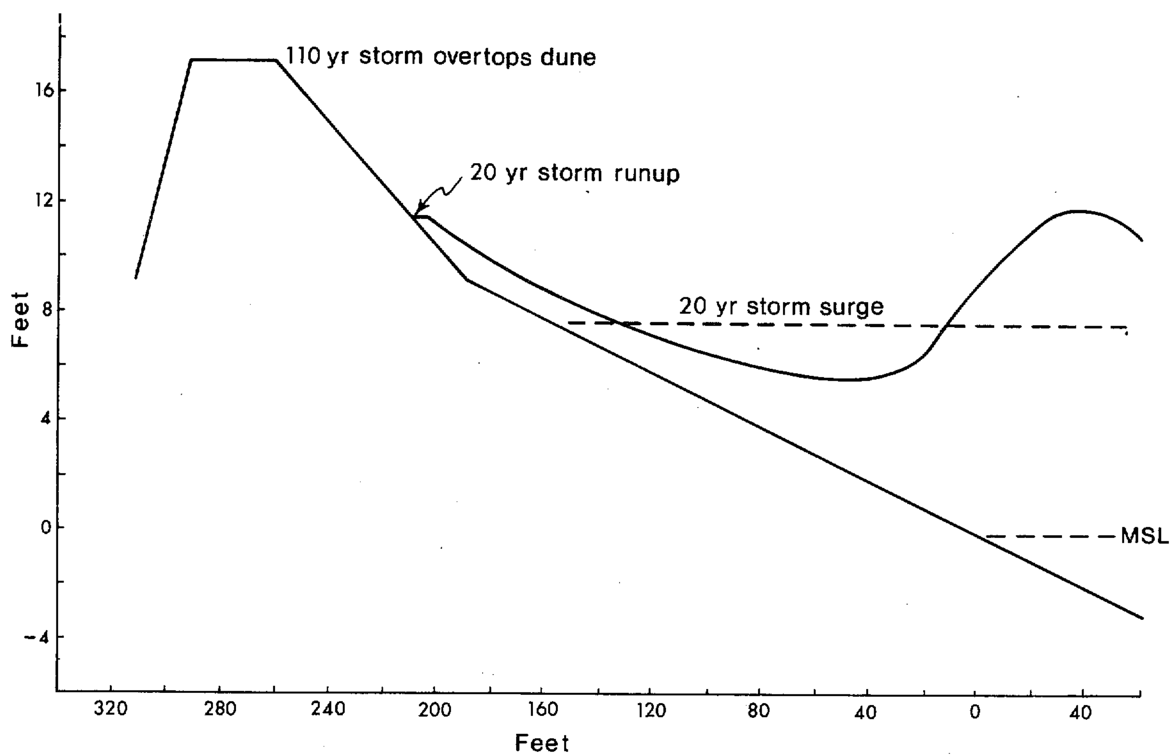


Figure 2-10. Predicted runup on Segment 2 design profile.

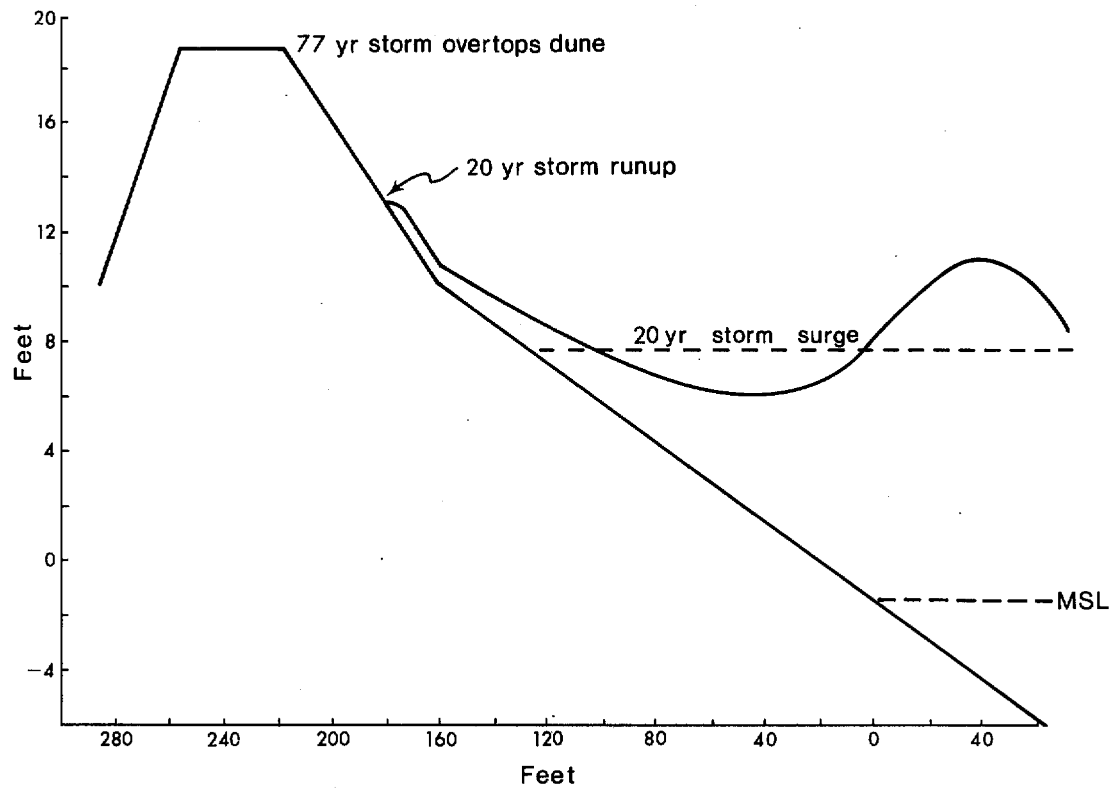


Figure 2-11. Predicted runup on Segment 3 design profile.

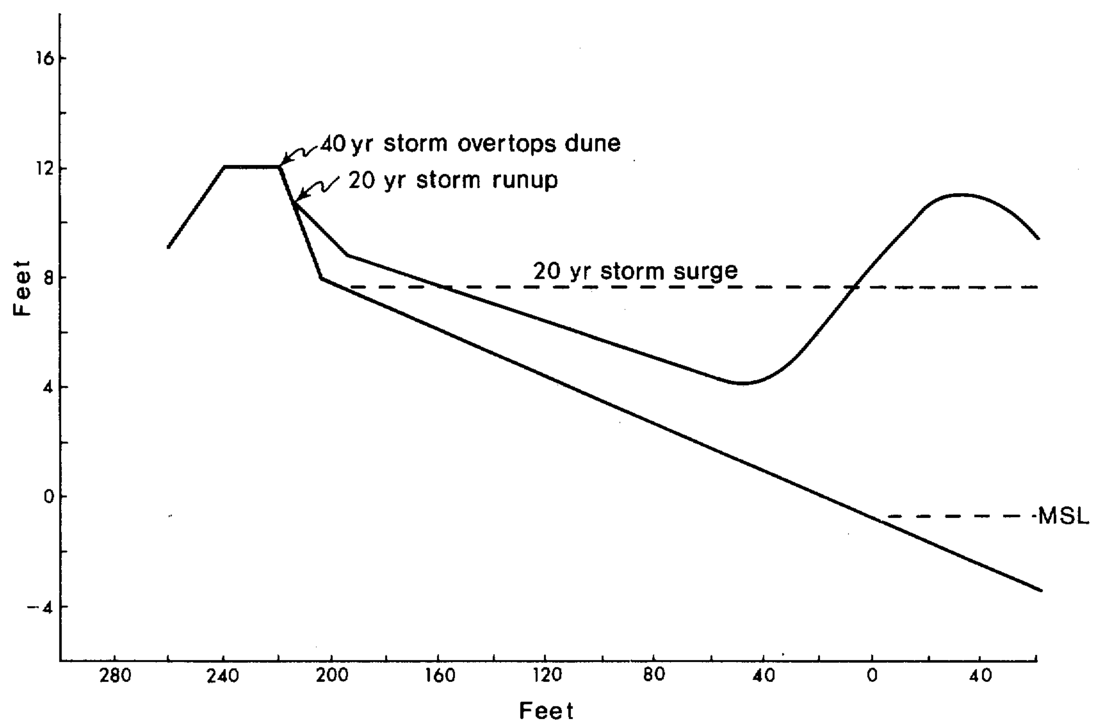


Figure 2-12. Predicted runup on Segment 4 design profile.

were obtained from as many data sources as possible. These included: 1) New Jersey beach profiles obtained for this study; 2) beach profiles taken by CCES researchers at Sandy Hook; and 3) beach profiles reported by Birkemeier (1979). The total number of cases for the regression was 99 and includes both bayshore and oceanshore dunes. The regression line (Figure 2-13), therefore, gives a generalized relationship between height and width.

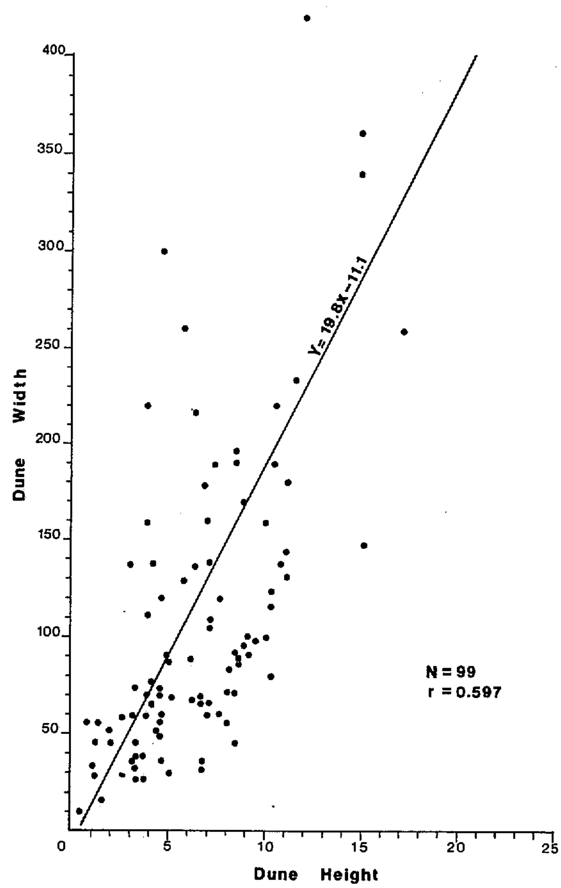


Figure 2-13. Dune height/width regression line.

One problem that arises from this regression analysis involves the data base. It must be recognized that the data set includes natural dunes (at Sandy Hook and Island Beach State Park) as well as artificial dunes. The northeasterly storm of March, 1962 destroyed many of the dunes which existed along the developed portions of the New Jersey shoreline. Following the storm, dunes were created by the U.S. Army Corps of Engineers, and these dunes remain today. In order to obtain a more natural height/width relationship, it would be desirable to intensively sample the remaining natural portions of the New Jersey shore and then to recompute the regression line. This may be necessary because natural dunes are frequently wider than artificial dunes. If the ultimate objective is to return the shore to a natural state, the natural characteristics should be employed. However, the cited relationship is appropriate for the initial creation of a Dune Management District. As time passes and the district is modified, a natural height/width relationship may be utilized if the required data are available.

2.2.3 Erosion Trends

The Dune Management District is designed to be broad enough to allow for the design dune as well as for the migration of the dune. This migration may be accommodated by a setback requirement that is related to the rate of shoreline displacement. The setback distance may be determined by adding the width of the design dune to the predicted erosion for some predetermined planning period. Predicted erosion rates are obtained by examining the historical record of shoreline change. In doing so, it is assumed that in the future, erosion will proceed at the same rate as in the past. This assumption is probably true in terms of a long-term average. However, it is recognized that short-term fluctuations may occur where for a few years erosion may cease, or accretion may even take place. The possibility that such variations might occur should be accounted for in dune district planning by implementing a review of the district boundaries at the end of the planning period.

The determination of past erosion rates, however, is difficult to accomplish. Three sources of this type of information have been identified (Dolan, et al., 1978a): 1) ground survey; 2) maps and charts; and 3) aerial photographs. It is generally agreed that ground surveys provide the most accurate record of shoreline migration. However, this type of survey is usually limited to only a few shoreline locations, and the historical record is generally quite short. It is, therefore, difficult to extrapolate long-term rates of erosion over a stretch of shoreline from one short-term profile.

Maps and charts have an advantage over ground surveys in that they can provide long-term information, dating frequently back to the mid-nineteenth century. Unfortunately, consistent coverage may be restricted to certain specific locations, and the early cartography was sometimes inaccurate.

Aerial photographs represent a good source of information, although coverage generally exists for only the last 40 years. There exist several limitations to the use of aerial photographs (Nordstrom and Psuty, 1977):

1) The identification of a point or a line on the photograph is difficult to replicate continually.

2) Scale differences between individual photographs may exist.

3) Variations in relief of the surface cause scale distortions on the photograph.

4) Variations in camera tilt produce scale differences.

The error which is associated with these problems can, however, be reduced to a minimum if proper cartographic techniques are followed and if the appropriate equipment is used. Under these conditions, aerial photographs may be considered reliable sources of information.

The use of aerial photographs to measure rates of erosion depends on the way in which beach width is measured. A cultural feature can easily provide a reference point inland from which to start, but the problem is the determination of where the beach stops. The high water line has been identified as a recognizable feature on the beach which appears to undergo little variation (Stafford, 1968; Dolan, et al., 1978a). The high water line can be identified by a distinctive change in color tone. However, Nordstrom and Psuty (1977) list several other such color lines which may be confused with the high water line. It is necessary, therefore, that the high water line be carefully identified.

Finally, it is necessary to recognize that natural fluctuations occur on the beach and that these may modify the determination of beach width and, therefore, of erosion rates. Nordstrom and Psuty (1977) identify three such variations: 1) tidal change; 2) cyclic change; and 3) seasonal change. The first and third may be compensated by photographing at about the same tidal stage and at about the same time of year. If the photographer is careful, it may be possible to photograph at the same time in the cyclic beach variation. However, these practices have not always been intentionally observed in the past. Some effort should be made to reduce the potential error associated with these variations in the future.

Long-term shoreline migration rates for New Jersey have been produced by the Corps of Engineers using historical charts (see Nordstrom, et al., 1977). However, these data are not used in this study because they do not reflect any changes which have taken place in the last decade. In addition, they reflect changes over the long term when the shore was both protected and unprotected, and thus a presently stable shoreline may be shown to be eroding.

Recent shoreline changes on the New Jersey coast have been identified by using aerial photographic coverage. Shorelines represented on aerial photographs taken in 1952 and 1971 were compared and the resulting erosion rates are presented in *Coastal Geomorphology of New Jersey* (Nordstrom, et al., 1977). These erosion rates are reprinted here in Table 2-2. Segments referred to in Table 2-2 may be identified from Figure 2-14. It should be noted that shoreline change rates for Raritan and Delaware bays, as well as for selected ocean shore segments, were not provided in that report. They have been calculated for this study and are represented in Table 2-2, although occasionally the time period may be different.

Dolan, et al. (1978b) also have presented erosion rate data obtained by adjusting photographs to a common scale, then superimposing a grid over the photographs, and reading beach widths at 100 meter intervals. These data are then used in a computer program

Table 2-2. Erosion rates for beach segments measured from aerial photographs (from Nordstrom, et al. 1977).

Segment	Change in ft/yr	Segment	Change in ft/yr
Fortescue	+2.18		
Fishing Cr. to Bidwell Cr.	-1.09		
1	+ 1.8	24	-
2	+ 4.2	25	-
3	+ 1.4	26	- 3.1
4	+ 0.7	27	+ 2.7
5	- 0.7	28	-
6	- 1.6	29	-
7	- 0.6	30A	- 5.4
8	+ 1.2	30B	- 8.8
9	- 7.3	31	- 5.2
10	- 4.5	32	+ 2.3
11	- 0.2	33	- 5.8
12	- 3.1	34A	- 4.2
13	- 4.7	34B	- 6.3
14	- 5.9	35A	- 4.3
15	- 1.3	35B	- 5.6
16	- 7.2	36A	- 6.9
17	- 3.6	36B	- 2.5
18	- 5.0	36C	- 3.7
19	- 6.1	37	- 0.8
20	-12.0	38	- 0.36
21	- 8.7	39	+17.4*
22	- 5.6	40	- 0.18
23	+ 0.7	41	- 4.65

*Area of significant beach nourishment

to produce a shoreline change map for the period 1930-1971. Although this period is longer by several years than the period used by Nordstrom, et al., the Nordstrom data are used in this report for several reasons. First, there are some problems with the Dolan methodology, namely in terms of the selection of the base line from which beach widths are measured. Dolan appears to propose using the edge of the map which is not an appropriate registration line to the air photographs. A cultural feature, such as a road, would seem to represent a better base line. Secondly, Dolan's average erosion rates are given for an entire island, and only for those islands to the south of Little Egg Inlet. Nordstrom, by contrast, divides the islands into segments where different erosion rates are identified. Further, Nordstrom presents data for almost all of the New Jersey shoreline.

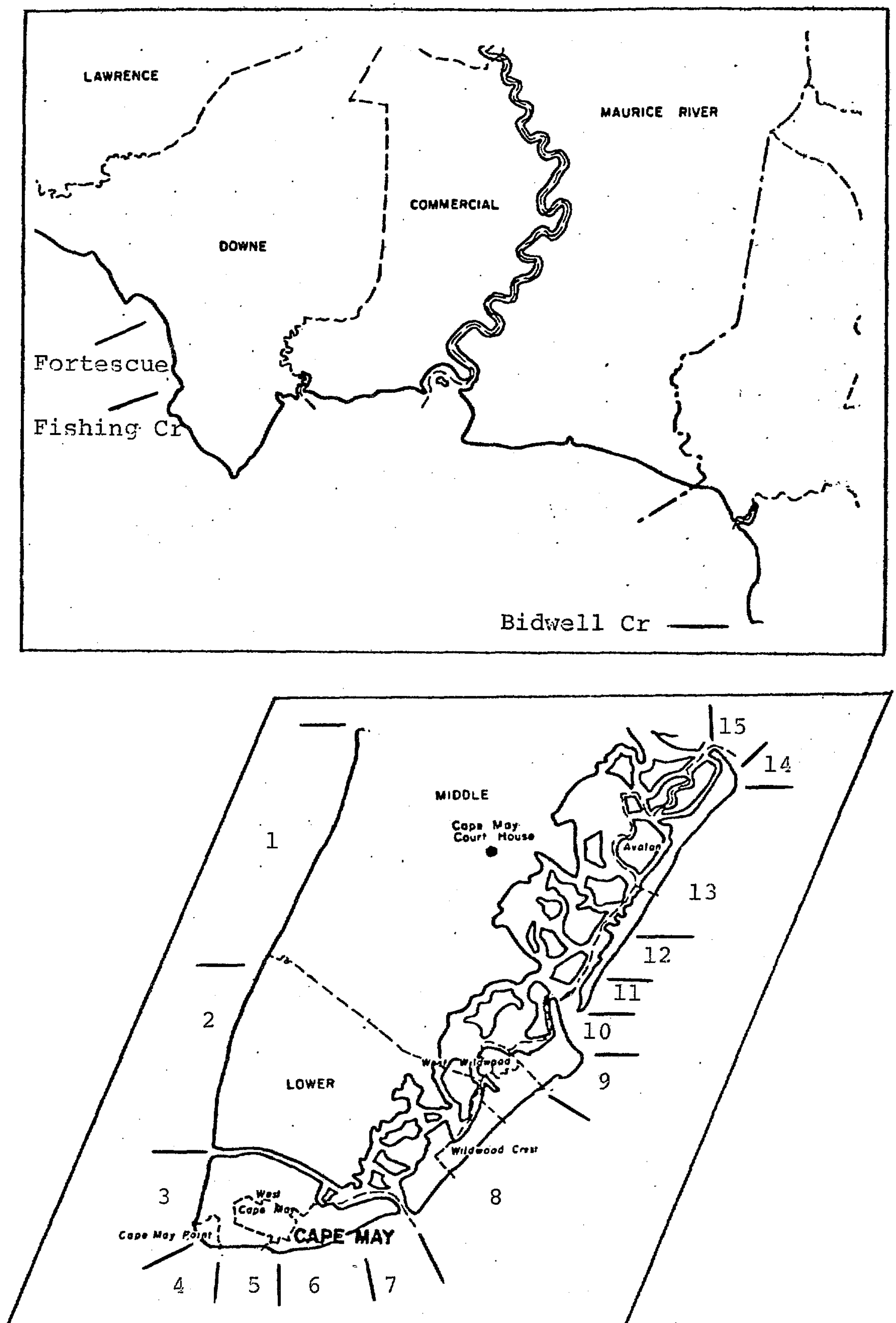


Figure 2-14. Shoreline segments referred to in Table 2-2 (from Nordstrom, et al., 1977).

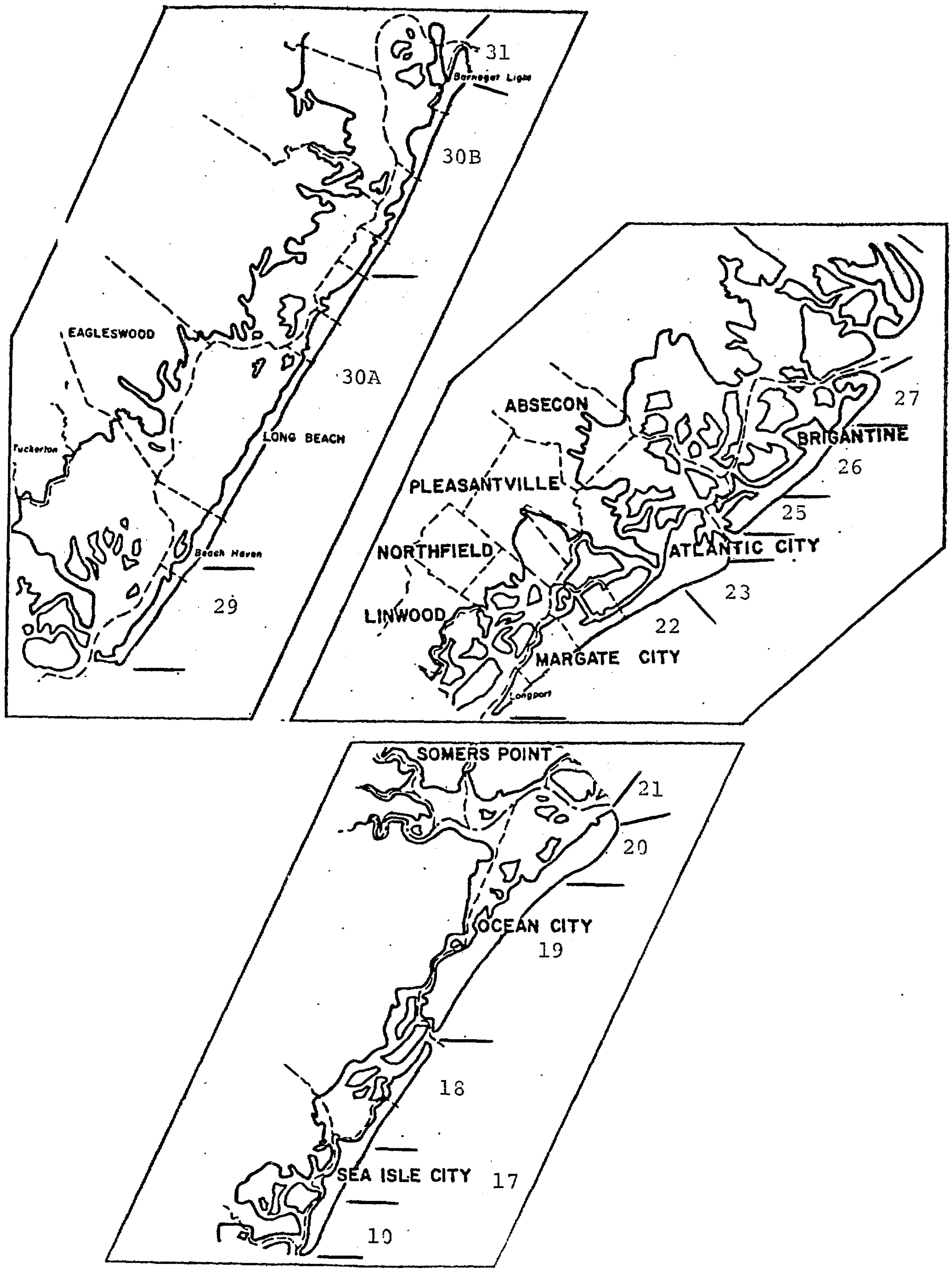


Figure 2-14. Continued.

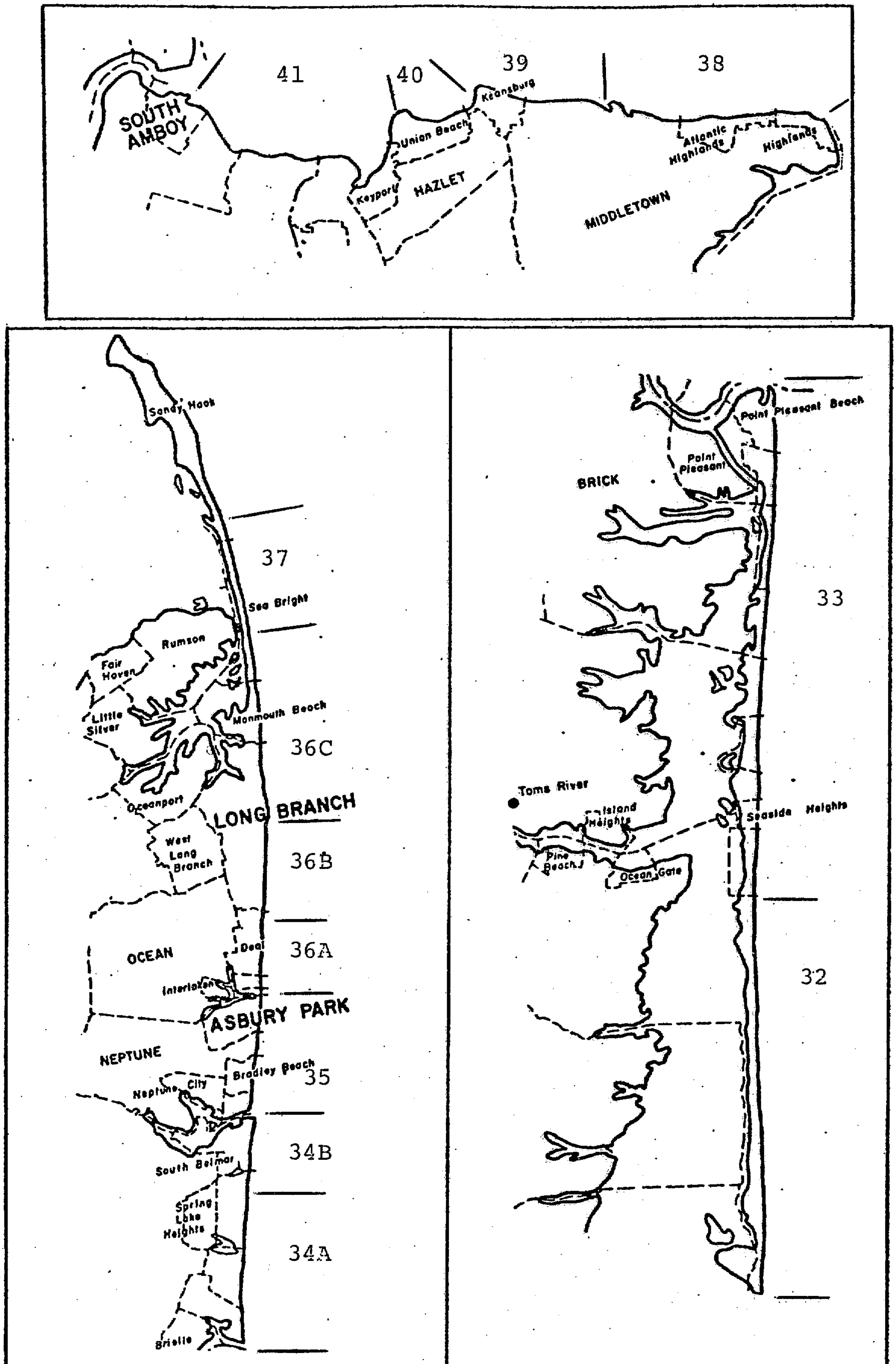


Figure 2-14. Continued.

It should be noted here that the attempt by Dolan and his colleagues to provide a systematic and easily replicable method of computing erosion rates is valid. However, the use of a stable, cultural base line would appear to be a logical modification to be made. Once this methodology has been applied to all of coastal New Jersey, the results could easily be employed in the Dune Management District delineation procedure. Until that time, it is suggested that the Nordstrom data be utilized.

2.2.4 Dune Management Areas Models

The determination of the width of the Dune Management District is accomplished through an analysis of runup, dune height, dune width, and erosion rate. Examples of the dune management delineation procedure are provided here for one sample location in each of the four shoreline segments (Figures 2-15 to 2-18) for a storm with a 50 year recurrence interval. The first step is to obtain from the appropriate runup curve the dune height which is necessary to protect against the 50 year storm. Next, a dune width value is obtained from the dune height/width regression line (Figure 2-13). Finally, the erosion rate for the shoreline segment in question is obtained from Table 2-2. This value, given in feet per year, is then multiplied by the number of years in the planning period. In the examples used here, the width of the Dune Management District is computed on the assumption that a 10 year planning period is in use. The width of the Dune Management District is computed simply by adding the width of the design dune to the amount of erosion predicted to occur during the time span of the given planning period.

Looking at the four examples, one notices variations in the width of the district. These result from two causes. First, the different beach and dune slopes of the design profile cause the runup values to differ for each of the four shoreline segments. Consequently, dune heights will also differ, and so will dune widths. Secondly, the erosion rates vary greatly along the shoreline. These differences are accounted for in the Dune Management District delineation procedure.

2.3 Designating the Degree of Protection

In the Dune Management District concept, a conflict arises between the amount of overwash required to maintain dunes and the amount of protection desired against flooding. Dunes can be built to protect against the extraordinary storm and to maintain the shoreline in a static position. However, barrier islands are maintained by overwash processes and inlet creation.

2.3.1 The Role of Overwash

The relative importance of dune migration, overwash, and inlet creation as mechanisms for barrier island migration has been the focus of several studies. In spite of limited empirical evidence, the concensus is that inlet dynamics are primarily responsible for the inland movement of barrier islands. One empirical study (Armon,

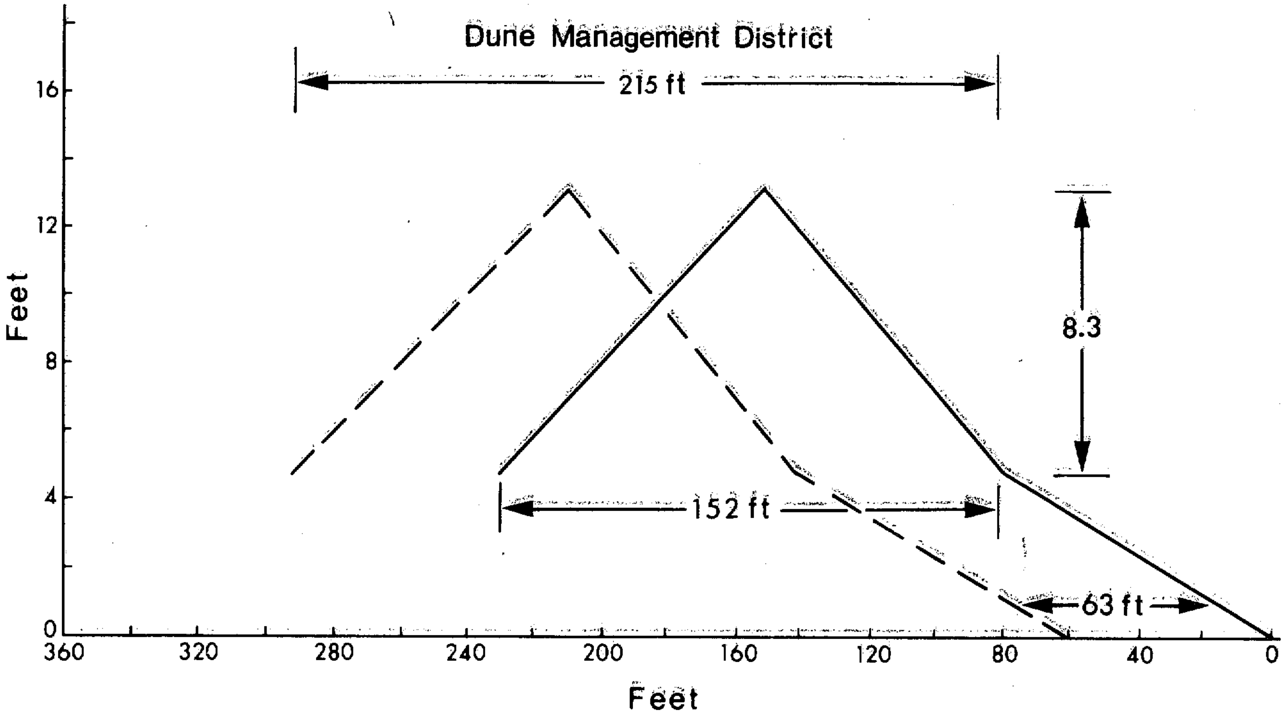


Figure 2-15. Dune Management District delineation procedure for Sea Girt area (Segment 1).

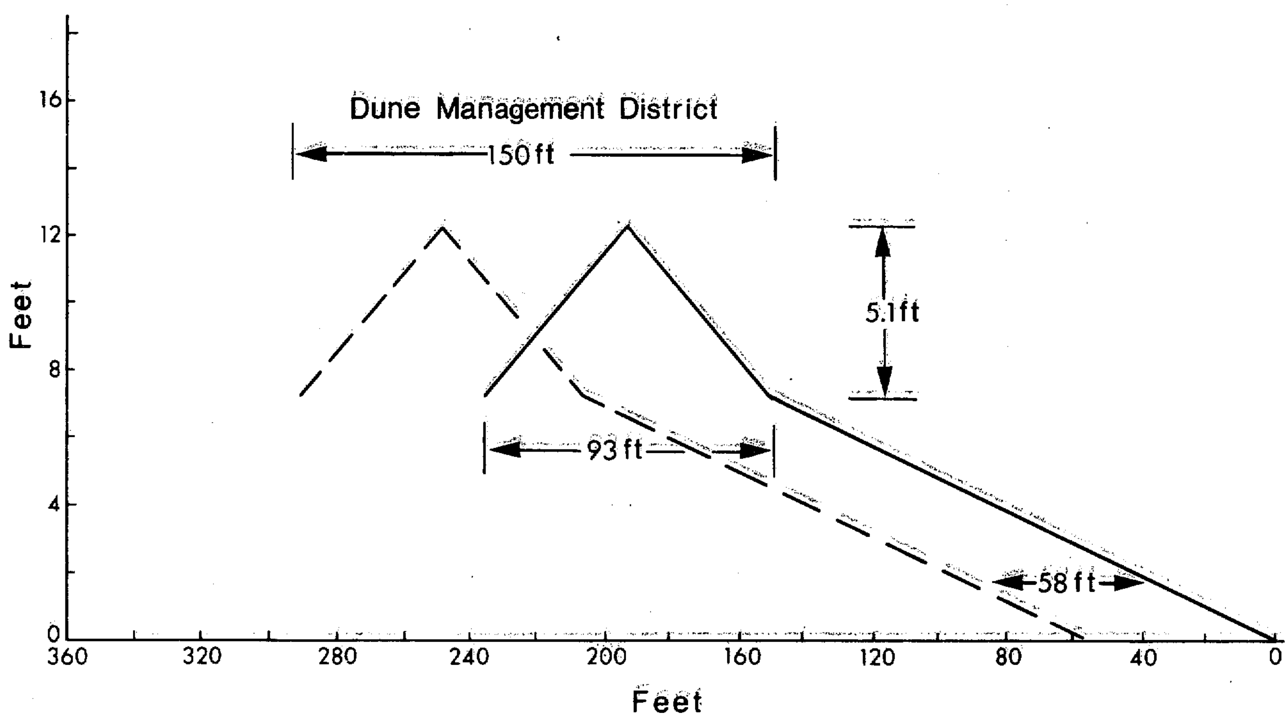


Figure 2-16. Dune Management District delineation procedure for Mantoloking Area (Segment 2).

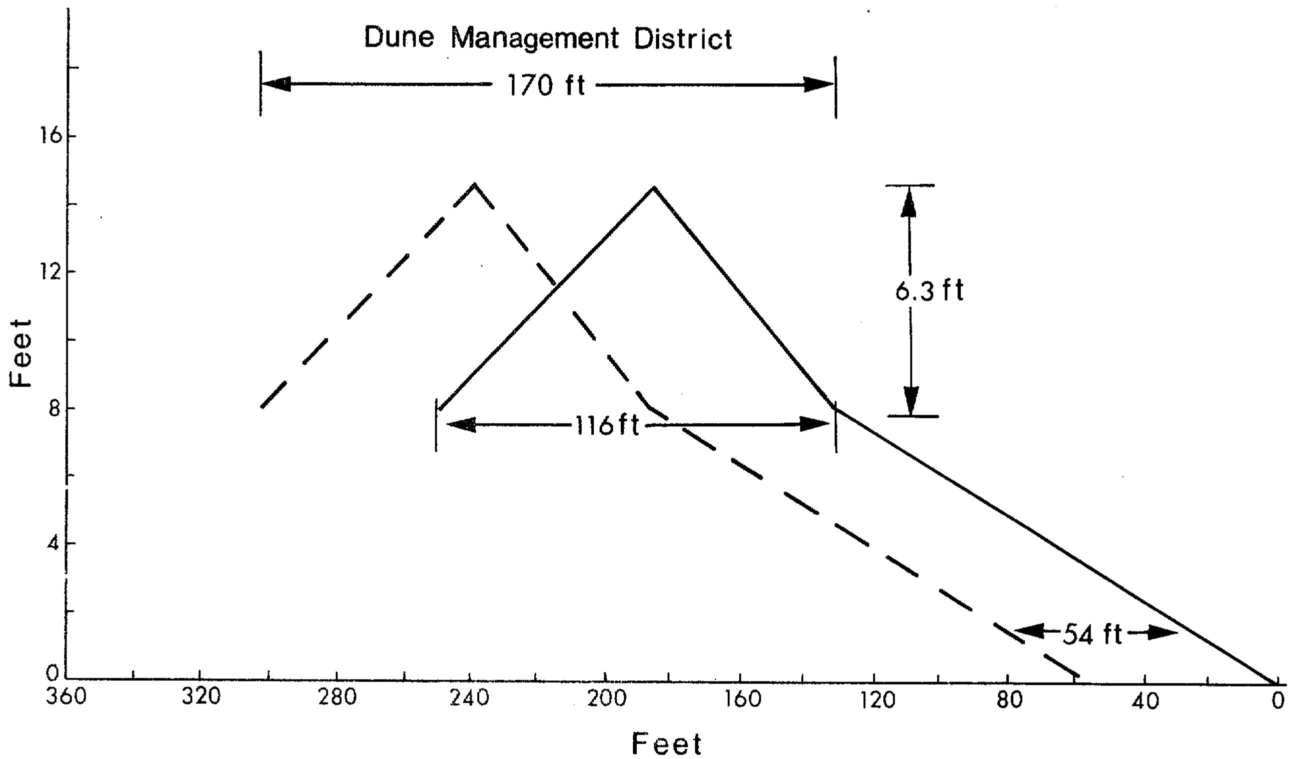


Figure 2-17. Dune Management District delineation procedure for Ship Bottom area (Segment 3).

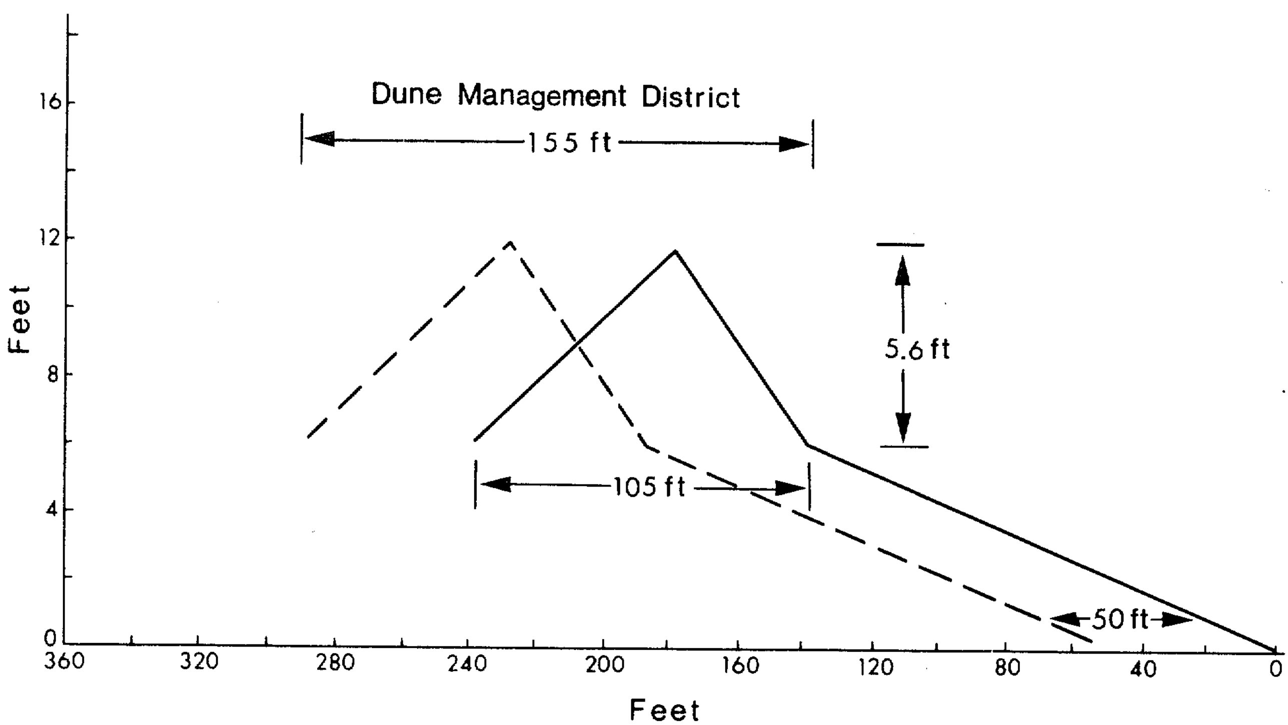


Figure 2-18. Dune Management District delineation procedure for Sea Isle City area (Segment 4).

1979) indicates that 90% of the landward sediment transfers at a Gulf of St. Lawrence study site took place through inlets. This finding supports Caldwell's conclusion (1967) that all of the inland retreat of the barrier islands in New Jersey could be attributed to the seven large inlets. In addition, by calculating a sediment budget for the southern barrier islands of North Carolina, Pierce (1969) has provided further support for the conclusion that the primary method of bayside growth of the barrier island system is by the transferal of sediment through inlets. He identified the contribution of the three processes as follows: 1) aeolian - 71,000 m^3; 2) overwash - 75,000 m^3; and 3) inlet transferals - 382,000 m^3. There is some question, however, about the method used to obtain these empirical values.

The above studies point to the overriding importance of inlet "losses" to the maintenance of the barrier island system. In those locations where natural processes are allowed to prevail, there is no interference with these sediment transfers. However, in New Jersey, navigation requirements and the desire to protect shorefront buildings have profound effects on these sediment transfers. Dredging and removal of sediment from inlets or sand bypass systems which transfer beach sediments from the updrift to the downdrift side of an inlet inhibit the growth potential of the backshore. In addition, the immediate closure of newly created inlets eliminates new channels for landward sediment transfers. Finally, stabilization of existing inlets prohibits natural closing. These policies maintain a static situation along the entire New Jersey shoreline in which inland sediment movement can only take place through stable inlets. It may be hypothesized, then, that in New Jersey, aeolian transfers and overwash are more important mechanisms for barrier island widening than in a natural setting.

Washover fans and tidal inlets are genetically related, and the resulting feature appears to be dependent upon barrier configuration, depths in the lagoon adjacent to the barrier, and the direction from which the storm surge came - ocean or lagoon side (Pierce, 1970). Leatherman (1979b) presents a model of barrier island dynamics on an undeveloped shoreline. The sequence begins with a barrier island characterized by a continuous dune line. As time passes, the beach narrows, permitting storm waves to attack and breach the dunes. Individual washover fans coalesce, and the dunes are eventually completely removed. The barrier island continues to narrow until an inlet forms. The inlet closes again when enough sediment has accumulated in the inlet channel. At the same time, sediment is deposited in a flood tidal delta which allows colonization by marsh plants and further stabilization of the delta. Eventually, the now subaerial flood tidal delta becomes attached to the barrier island creating the typical lobate shape which characterizes the backshore of many barrier islands.

This model helps to conceptualize barrier island migration and the processes that affect that retreat. On a developed coastline, such as New Jersey's, some modification to the model is necessary. However, there is a major lack of information about how development modifies the processes and their subsequent responses.

On developed shorelines where dune building is a common practice, the height of the dunes is a major factor in determining the amount of overwash that can occur. The presence of impermeable surfaces determines how far inland the overwash can penetrate. The following discussion of the effects of the March, 1962 storm on overwash on the New Jersey shoreline is presented to identify the importance of dune height and cultural factors as they affect overwash and the barrier island sediment budget. The discussion thus investigates the following: 1) an evaluation of damage expected from large storms; 2) the practicality of protecting against large storms; 3) a feeling for the relative contribution of overwash to barrier island migration; 4) the potential for inlet cutting; and 5) the implications for land use of protecting (or not protecting) against such a storm.

In terms of both the amount of overwash created and the amount of damage done, the March, 1962 storm did not have the same effect on all portions of the New Jersey shoreline (Table 2-3). Harvey Cedars (Figure 2-19) was one of the hardest hit of the barrier island communities, and damage to dunes and structures was considerable. Any dunes, if they existed before, were destroyed, and there remained few areas of high ground left unscathed. There was a veneer of fresh sand everywhere on the barrier island surface, although the major overwash fans appeared to exist where streets were located. Thin sheets of sand between the fans or bayward of them may represent settled sediment which was carried in suspension by the flood waters.

Table 2-3. Distances associated with maximum and minimum overwash penetration during the March, 1962 storm for selected locations in New Jersey (Source: NJDEP Aerial Photos).

Maximum Penetration	Minimum Penetration
Surf City 2,500' (total overwash)	Brigantine Beach 330'
Ortley Beach 2,900'	Seven Mile Beach 500'
South Mantoloking Beach 1,000' (total overwash)	Five Mile Beach 50'
Sea Isle City 3,500' (total overwash)	North Wildwood 40'

At Harvey Cedars, overwash often penetrated to the bay, even where there were bayside bulkheads. Locations where new inlets might form are located at the site marked A and to a lesser extent at the site marked B on the photograph. Sediment was delivered into the lagoons, and dredging may have taken place. The removal of washover sediment by dredging represents a loss of potential salt marsh substrate at that location. Cost-benefit realities of dredging would have

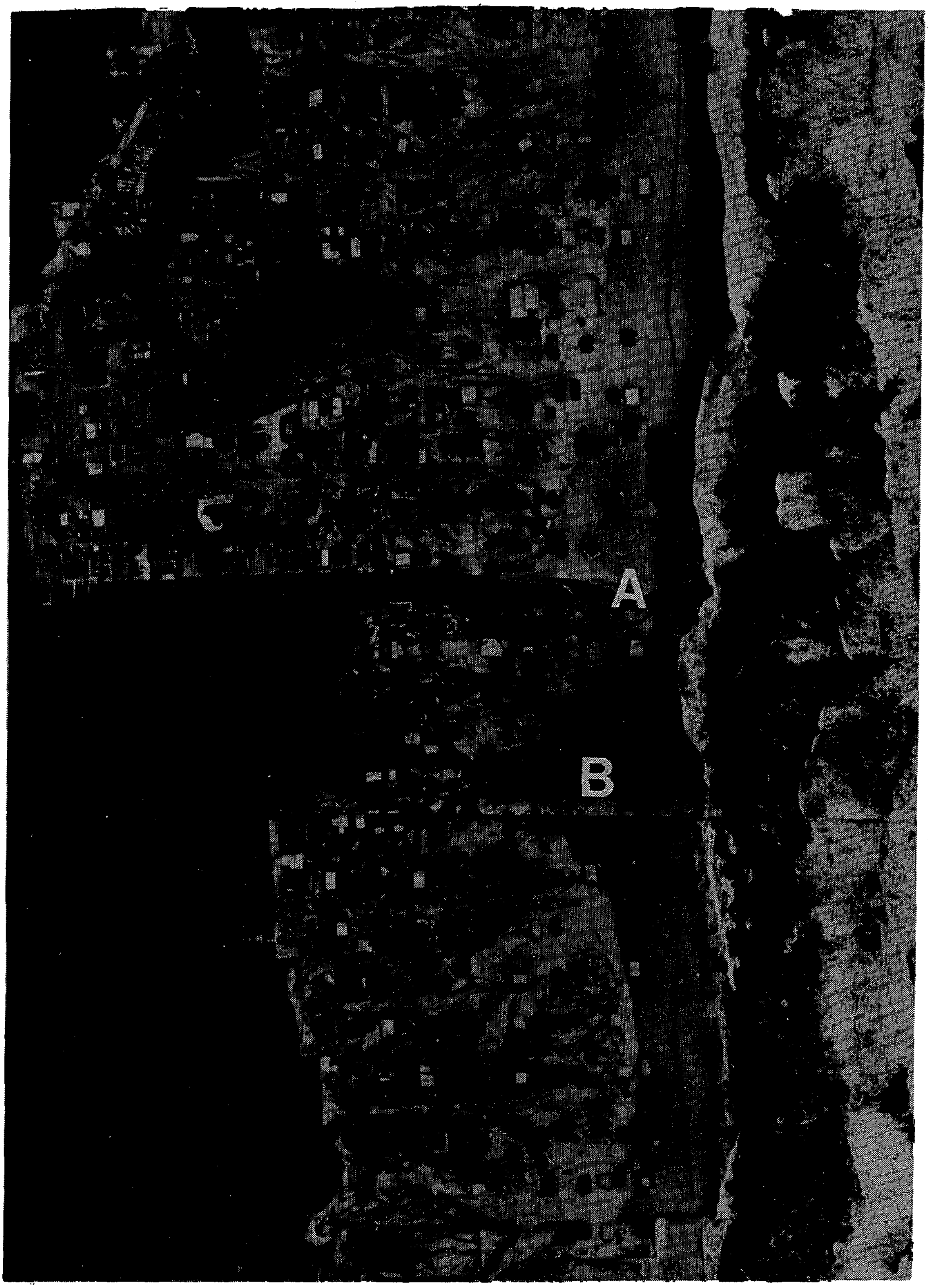


Figure 2-19. Harvey Cedars, New Jersey showing overwash for the March, 1962 storm (Source: N.J. Bureau of Coastal Engineering Aerial Photos NJC-3BB-125/127). (Scale: 1"= 308 ft.).

prevented their being emplaced on the backside of the barrier island in a configuration that would favor the growth of *Spartina* marsh. However, the emplacement of these sands back on the beach would have been an easier matter.

Following the storm, there was minimal protection from flooding and overwash. In such cases, decisions must be made on how to recreate the protective dune (i.e. through fencing, planting, and bulldozing) and where to try to establish the new dune. Following a storm, a decision must be made as to how much of this sand can (and should) be allowed to migrate back to the dune/beach zone by natural processes.

In North Carolina, under natural conditions, a period of five years was sufficient to reform an overwashed dune ridge to the point where it provided protection against the March, 1962 storm (Hosier and Cleary, 1977). However, this same time period cannot be assumed to apply on the developed shoreline of New Jersey. This question should be the object of further study.

Another option which exists following a storm is to bulldoze the overwash sediment back to the location of the former dune. In the case of the 1962 storm, the loss of sand on the oceanside was compensated by the creation of a new dune using sediments dredged by the backbay. This project, conducted by the Corps of Engineers, involved the emplacement of 2.17 million yds^3 of sand for beach fill (Wicker, 1964).

Leatherman (1979a) points out that in locations of high dunes, it appears that only extremely large events are important for landward sediment transfer. He identified the 50-100 year storms as the major agents of such work. Overwash did not penetrate through the dune zones at the two locations of highest oceanside dunes in New Jersey (locations marked A on Figures 2-20 to 2-21). In contrast, adjacent developed areas suffered overwash and related destruction of the existing dune. In the case of Island Beach State Park (Figure 2-20), dune walkover trails and the impermeable parking surface caused increased accumulation of sediments as evidenced by the overwash fan so prominent in the photograph at location B. Both Figures 2-20 and 2-21 demonstrate two important points: 1) where the dune is high and wide, it can function as a complete barrier to overwash; and 2) a natural dune may not be overwashed by a storm with low recurrence interval.[1]

Avalon (Figure 2-21) was hit less hard than Harvey Cedars. There was no overwash to the bay along the entire width of the barrier island. Where the dune was high and wide (A), there was minimum penetration of overwash. In the adjacent area to the north (B), there

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[1]The 1962 storm has been described as a 100 year storm (Bosserman and Dolan, 1968). Leatherman (1979a, p. 7) also noted that on much of Assateague Island, overwash from this storm was ineffective in landward barrier migration.

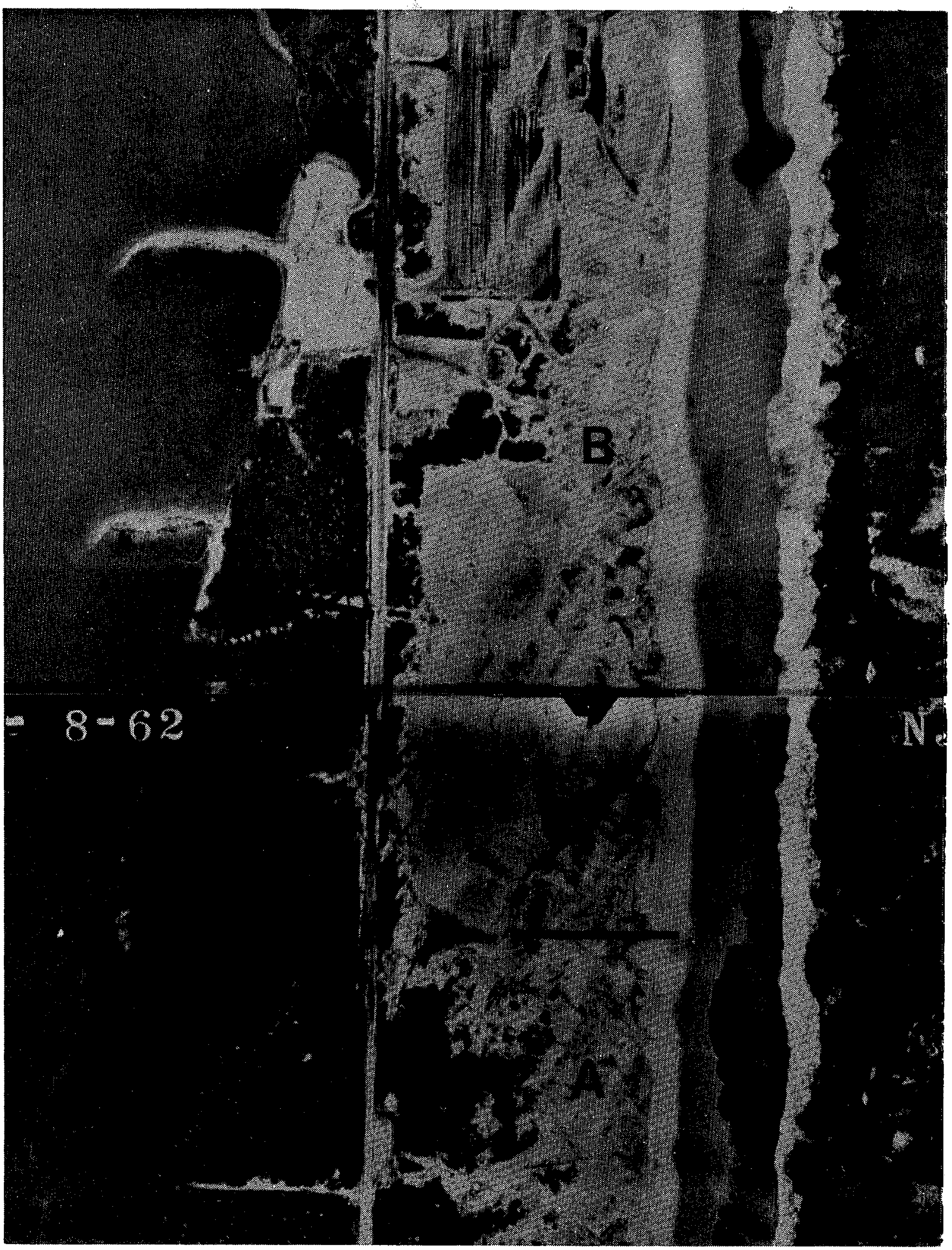

Figure 2-20. Island Beach State Park showing overwash from March, 1962 storm (Source: N.J. Bureau of Coastal Engineering Aerial Photos NJC-3BB-77/79). (Scale: 1" = 316 ft.).

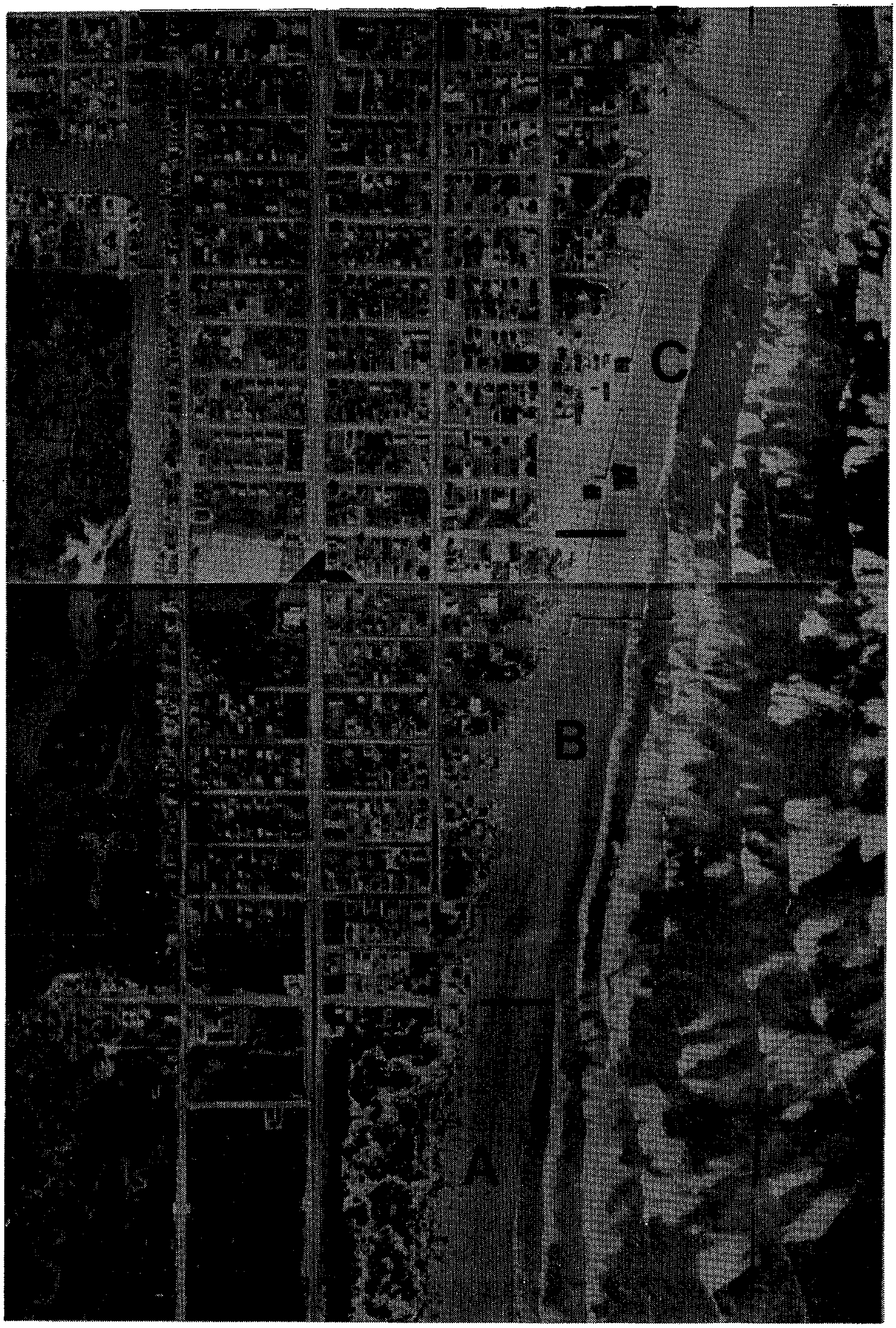

Figure 2-21. Avalon, New Jersey showing overwash from March, 1962 storm (Source: N.J. Bureau of Coastal Engineering Aerial Photos NJC 4BB-43/45). (Scale: 1" = 832 ft.).

appeared to be overwash through low points in the dune at beach access locations at the ends of streets. Farther north (C), larger portions of the barrier island had washover. It is not known whether the dunes were lower here. Increased overwash could also be attributed to more gaps in the dune, a narrower pre-storm beach, or a local focussing of wave energies. Any, or all, of these factors would also account for the greater damage at Harvey Cedars relative to Avalon.

Sediments were delivered inland in all locations along the shoreline of New Jersey by the March, 1962 storm. These occurred as either overwash fans or a thin veneer of sand deposited by flood waters. In only a few cases, the sand was deposited in the bay creating new substrate for salt marsh and increasing the width of the barrier island. However, in many locations, overwash fans on the sub-aerial portions of the island increased ground elevation. Deeper penetrations of overwash appeared to occur at locations where streets perpendicular to the shore met the shoreline, either because of low elevations in the dune created for beach access or because the impermeable road surfaces allowed water and sediments to travel farther bayward.

A critical question which comes out of this discussion concerns the degree to which the dune will function as a barrier to overwash. If dune districts are created in which no overwash is allowed, there will be no sediment delivered by this process to build up the landward edge of the dune. Unless there is net onshore migration by aeolian processes, the dune crestline and the landward limit of the dune zone will remain relatively stable in position. The result could be a gradual elimination of the beach from in front of the dune and eventual dune destruction with elimination of its protective function. Landward migration of the dune through overwash or some other process is, therefore, required to maintain the integrity of the dune (Nordstrom and Psuty, 1978).

If there is no mechanism for sediment to be delivered to the backbays, the continued migration of the beach/dune profile will gradually diminish the width of the barrier island. Dune Management District regulations provide a mechanism for the maintenance of the dune system. However, maintenance of the integrity of the barrier island is also required, either through inlet creation or overwash (both of which are most often associated with storms of greater recurrence interval than 50 years) or the creation of salt marsh substrate using dredged material. The latter is particularly appropriate in developed areas where frequent dredging, resulting from high intensity boat use, will supply considerable spoil material.

2.3.2 Protection Requirements

Since the dune ridge is affording protection against storm surge, a decision must be made as to the degree of protection required. As previously cited, Leatherman (1979a) suggests that storms with a 50 to 100 year recurrence interval are responsible for the majority of the landward transfers of sediments. Leatherman further suggests that areas where overwash is frequent will remain unvegetated. The result is that dune growth through entrapment of sediments by vegetation will be minimal. To ensure that natural dune building processes will be operative, it appears desirable to reduce the frequency of overwash. Following these arguments, it appears unreasonable to use anything less than the 50 year storm as the design storm in the establishment of dune management districts.

In terms of natural processes, there appears to be no reason why a natural dune cannot afford protection against a storm with a recurrence interval of 100 years. However, the width of the dune zone required to maintain a dune of sufficient dimensions would be considerable. A dune zone designed to protect against a 100 year storm will reduce the amount of overwash and will, thus, limit dune migration.

A major factor to be considered in terms of protection level is the cost of implementing the design dune. In New Jersey, there exist very few dunes which have the height/width characteristics necessary to protect against a 100 year storm. Whatever design storm is adopted, a uniform dune height-width code will have to be enforced. If the 100 year storm is selected, great expenditures of money will be necessary to build the dunes to the required elevation.

There are several arguments in favor of selecting the 50 year storm as design storm for the Dune Management District delineation procedure. First, the design dune has the advantage of providing protection against low intensity storms which occur relatively frequently. Secondly, the design dune should migrate at a rate which allows owners of destroyed houses to be evacuated slowly enough to permit them to draw some benefit from their investment. Thirdly, New Jersey dunes are such that little modification is necessary to conform to 50 year dune dimensions. Fourthly, a 50 year dune allows for natural washover processes to occur, and dune migration, in response to a rising sea level, will result.

At this time, it appears that the 50 year storm represents the most logical design interval. The Dune Management District delineation procedure employed in this report is based on the adoption of the 50 year storm as the design storm. One problem which must be solved concerns the false sense of protection which residents may feel as a result of the implementation of a design dune. It should be emphasized that the dune only protects against frequent storms, and residents should expect damage from severe storms. In addition, the selection should be reviewed if new information becomes available.

Section 3 - Dune Delineation Procedures

3.1 General

An important objective of this project was to represent cartographically the data that were obtained during the course of the study. Cartographic work focused on two subjects: 1) the New Jersey dunes; and 2) the dune management areas.

3.2 New Jersey Dunes

In order to conform to the concepts emphasized in this report, the dune classification system is designed to categorize the dunes according to their height and width characteristics. Height and width data were obtained primarily from the 63 profiles taken in the summer of 1979 along the New Jersey shoreline from South Amboy on Raritan Bay to Fortescue on Delaware Bay. The locations of the profiles were plotted on a map. Preliminary dune segments were established by evenly dividing the area between profiles (Figure 3-1). Aerial photographs taken in 1977 were then used to identify shoreline stretches where dunes are absent. The dune segment lengths were modified accordingly.

In order to represent dune characteristics cartographically, height and width categories were established. Height categories were divided into three foot intervals, whereas width categories are not all equal (see Plate I). Dune height and width values for each profile were obtained from the survey data and were assigned to the appropriate classification category. Thus, for example, a dune whose height is 4.8 feet falls in the 3 to 6 foot category. Similarly, if its width is 80 feet, it is assigned to the 50 to 100 foot category.

Each profile line was considered to be representative of its dune segment. Consequently, since the height and width of the dune at each survey line was categorized, the dunes within each segment are represented not in terms of a specific value but rather in terms of a range of values. Thus, dune heights in a certain segment may be said to be in the 6 to 9 foot range, for instance. Although this methodology generalizes the dune characteristics, the procedure does reduce the error which results from assuming the profile information is representative of adjacent areas.

New Jersey dunes have been represented on a map with a scale of 1:250,000 (Plate I). The use of categories allows one to obtain a general idea of dune heights and widths on various segments of the shoreline. More detailed information could be obtained by using contour lines with small intervals on large scale maps such as the 1:2,400 DEP wetlands maps. This may be a desirable project for the future.

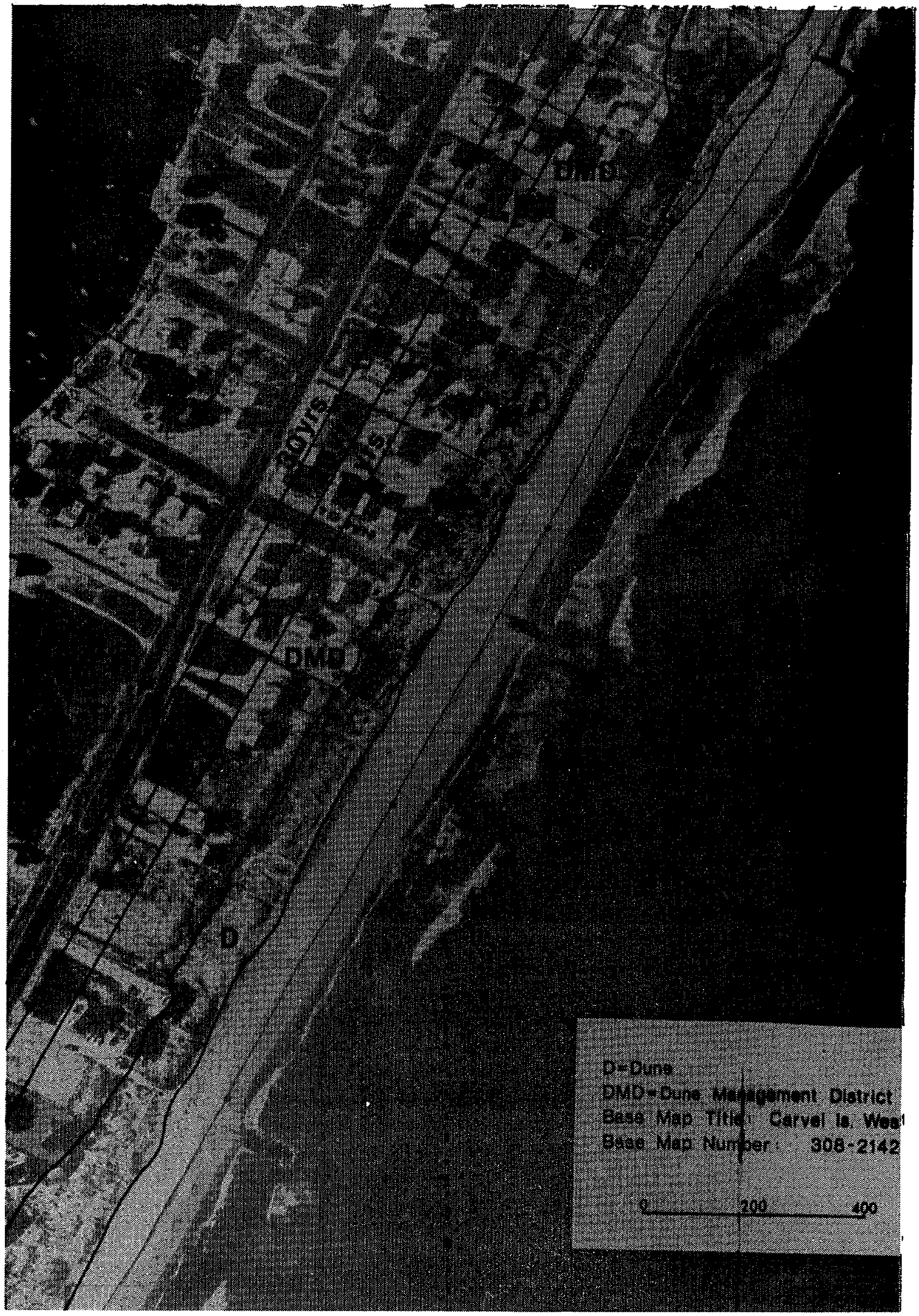

Figure 3-1. Example of Dune Management District maps showing the predicted locations of the landward boundary of the district for selected 10 year intervals.

3.3 Dune Management Areas

Because of the need for greater precision, dune management areas are mapped at a scale of 1:2,400. Mapping is in the form of overlays designed to fit over DEP wetlands maps. The overlays are registered to the base maps using longitude and latitude as registration points.

Represented on the maps are two sets of information. A polygon identified as "D" indicates the dune crest zone in its most recent form. A stereo zoom transfer scope was used to observe this area on 1977 aerial photographs and to transfer the information to maps at a different scale. This exercise was undertaken for the entire shoreline of New Jersey, and the set of overlays accompanies this report. If it is decided to develop contour maps of the dune zone, this area may be represented on these overlays.

A second area identified as "DMD" represents the proposed Dune Management District. The width of this area was calculated according to the procedure presented in Section 2. Care was taken to recompute the width of the district for each of the four shoreline segments identified in this report. In addition, erosion rates for some thirty shoreline segments are available from Nordstrom, et al. (1977). These were accounted for in the computation procedure.

The Dune Management District maps (Figure 3-2, for example) consist of the dune zone (D) and the dune management zone (DMD). The Dune Management District is determined by the calculation procedure described in Section 2. The width of the district is measured from the seaward boundary of the dune crest zone (D). Three lines are located to the landward side of the dune zone. These represent the initial landward limit of the management district for the 10 year planning period and projected landward boundaries for the second and third planning periods 20 and 30 years hence. The projected management district boundaries are based on current yearly erosion rates and are modified into a 10 year erosion rate. This 10 year rate is added to the initial management district width to establish the future landward limits. The projected boundaries, however, are based only on data currently available. The limits of the Dune Management District must be reviewed at the conclusion of the first planning period to account for variations in the erosion rate during that time. In addition, new data or new techniques for determining erosion rates may become available, and they should be accounted for during the boundary review.

Mapping the Dune Management District along the entire New Jersey shore is not entirely free of problems. Wave and surge data for Atlantic City are assumed to be representative of the entire coastline. However, these data are not representative of bayshore areas because of different shoreline orientations and fetches and generally higher tidal ranges. These problems have made it unrealistic to map Dune Management Districts on Raritan and Delaware bays. Therefore, on these shorelines only the dune areas are represented on the 1:2,400 overlays. It is recommended that the state begin an intensive data gathering project for these areas if Dune Management Districts are to be implemented along these shorelines.

It is necessary to recognize that the headland area of the New Jersey shoreline also presents a unique situation. This area, located between Long Branch and Manasquan, is a cliffed shoreline where dunes are largely absent. The higher elevations which characterize the area are not subject to flooding, but erosion remains an important concern. Consequently, shoreline management in the headland zone need not focus on dune protection. The erosion problem may be dealt with through the use of construction setback lines which are related to the erosion rate. While the establishment of setback lines may require a new methodology for this project, the landward limit of a Dune Management District has been represented on the maps of the headland zone. It is suggested, however, that complete review of management practices in this shoreline zone be undertaken perhaps in conjunction with the work on the Shore Protection Master Plan.

3.4 Use of the Maps

These maps are used for illustrative purposes and to provide preliminary evidence in support of Dune Management District legislation. However, as presented, this district is shown in terms of information portrayed on aerial photographs taken in 1977 and on wetlands photo-maps taken in 1972. In particular, the seaward limit of the district shown here is the high water line represented on the 1972 aerial photographs. Shoreline changes since that time may be great. Beach nourishment projects, such as the one at the northern end of Long Beach Island, have taken place which widen once narrow beaches. The Dune Management District must be delineated in terms of the current location of the dunes and the shoreline.

Dune Management District legislation may adopt the techniques for delineating the district presented in this report. However, an important component of the legislation should deal with redelineation based on current data. Of the available techniques for updating the shoreline location, ground surveys do not cover enough area, and high altitude imagery has not yet been shown to have enough precision in a dynamic area such as the coastal zone. Aerial photography represents the best available technique for updating the location of the shoreline. Several advantages can be cited:

1) The conditions for the photography can be controlled by the client so as to offset the possibility of error (see Section 2.3).

2) Aerial photographs may be used stereoscopically to obtain elevation information.

3) Cultural points may be easily identified for registration with maps or photographs at other scales.

4) Aerial photography can easily cover the entire shoreline.

5) The expense for new photographic flights is relatively low.

In spite of these advantages, legislation should be designed to allow for the use of any new techniques for shoreline delineation that may be developed in the future. If, for example, high altitude imagery is shown to have the required precision, it may be substituted for the aerial photography.

Another problem which should be addressed by the legislation concerns the review process at the end of the initial planning period. Any redelineation of the district at that time should be based on new aerial photography, or on any new shoreline identification technique. Furthermore, in the event that an extraordinary storm were to occur before the end of the planning period which effectively damaged or destroyed the dunes, some mechanism for early review must be allowed in the legislation. Aerial photography would be required as soon following the storm as possible to permit the redelineation of the Dune Management District.

It is important to recognize that the beach/dune zone is dynamic and that, therefore, any dune district delineation must be based on current information. While the technique employed herein may be included in dune management legislation, the areas represented on the accompanying maps should not be adopted outright. New aerial photography will allow the redelineation of the district based upon the methodology presented here. This new Dune Management District may then become the legal management district.

Section 4 - Performance Criteria

4.1 General[2]

The integrity of the dune system must be preserved if it is to perform its protective functions. To accomplish this, more restrictive regulations concerning development and use of the dune zone are required than were employed in the past. In addition, the shoreline residents must be well informed about barrier island dynamics and about the solutions to the problem of shoreline erosion. A comprehensive program of development restriction and public education will result in better management of barrier island resources.

This section examines performance standards that may be implemented in Dune Management Districts. The standards discussed here are designed to protect the integrity of the natural beach/dune system. This objective differs from the goal of more traditional approaches to performance criteria which sought to reduce the damage potential to the structures themselves. In many cases, the performance standards required for protection of houses and facilities are compatible with those required to insure maintenance of the natural system. However, there are sufficient differences in the effects of these two approaches to warrant a complete revision of the approach to shoreline management through the implementation of performance standards. The discussion includes an analysis of the ways in which the dune form can be affected by: 1) direct destruction of the dune by walking and driving on the dune or by construction on the dune; and 2) interference with the manner in which the dune is created and is maintained through sand transfers.

4.2 Destruction of the Dune Form

4.2.1 Dune Traffic

Walking or driving on the dune may occur as a result of the desire to gain access to the sea or of a desire for recreation use of the dune environment such as dune walks or dune buggy riding. In the former case, the result is a destruction of anchoring vegetation and a subsequent lowering of the dune surface in localized ribbons extending normal to the shore. Direct recreational use of the dune environment may result in the destruction of more of the vegetative cover and a lowering of the dune form both parallel and perpendicular to the shoreline. Such unrestricted recreational use of the dunes must be prohibited in all locations if the dunes are to remain as a viable form of protection. However, even if restrictive legislation is employed, it will still be necessary to provide access to the sea. Such pathways can be elevated to reduce interference with dune dynamics. Where no walkover structures are provided, the integrity of the dune can be maintained by periodic replenishment of sand to raise the pathways to the required crest elevation. The importance of these low

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[2] This section expands on a discussion found in Nordstrom and Psuty (1978, p. 18-24).

elevations in the dune cannot be overemphasized. The U.S. Army Corps of Engineers reported extensive dune loss from the March 1962 storm in those areas in New Jersey where streets penetrated the dune ridge and extended almost to the backshore. In the town of Avalon, for example, waves flanked the dunes on both sides of each street and almost complete loss of the backshore beach and of most of the dunes occurred over a reach about 6,200 feet in length. Where no street penetrations occurred, the dune line remained intact and there was no major flooding landward of the dunes (U.S. Army Engineer District, Philadelphia, 1962, p. 20).

4.2.2 Construction on the Dune

In certain locations along the shore, dunes have been bulldozed down to provide views of the sea from the living rooms of shorefront residences or from boardwalk surfaces flush with the beach elevation. In addition, dunes have often been bulldozed down to facilitate construction of houses and the support facilities required for these residences. In many cases, such bulldozing practices have not been prohibited provided the dune is not lowered beyond a certain required minimum elevation. The extra measure of protection which would be afforded by the greater quantities of sediment in the local high crest elevations is thus lost. Further, the construction of these houses and support facilities virtually insures that if a dune is allowed to form, it will be stabilized in a location in front of these structures well seaward of its equilibrium location. This will restrict the width of the beach and limit its value for protection and recreation, and the dune will be subject to more frequent attack by storm waves.

In many municipalities, direct destruction of the dune form is prevented by legislation, and it is unlikely that many of the abuses which have occurred in the past will continue in these locations as long as the regulations are enforced. However, as of 1978, there were still a great number of municipalities in New Jersey which did not have adequate dune protection ordinances. Table 4-1 reveals that of the 48 shorefront communities surveyed, less than half have dune ordinances. Further, many of the communities which do have dune ordinances do not legislate against such destructive practices as breaching or lowering of the dune and walking or driving on the dune. At present, the ordinances reflect the maintenance of a status-quo condition or a stationary dune.

New dune ordinances must be passed and implemented in those communities which do not presently have a legal means for protecting the dune. In those communities which presently have dune ordinances, new criteria must be applied which will insure protection of a migratory dune.

4.3 Interference with Dune Construction and Migration

4.3.1 General

The problems associated with the modification of dune processes involve not only the interference with the processes but also the

Table 4-1. Summary table of community responses to dune district questionnaire (from Nordstrom, Psuty and Fisher, 1979).

Number of shorefront communities	48
Number of communities with dunes	27
Number without dunes	21
Number with dune ordinances	21
Points covered in dune ordinances	
Lowering or breaching prohibited?	
Yes	13
No	8
Removal of sand or vegetation prohibited?	
Yes	18
No	3
Walking and driving prohibited?	
Yes	14
No	7
Other zoning or building ordinances	
Are setbacks required?	
Yes	24
No	11
No response	13
Are 1st floor minimum elevations or pilings required?	
Yes	20
No	14
No response	14
Existing dune maintenance program?*	
Yes	13
No	21
No response	8

*6 communities leave the maintenance program up to individual owners.

removal of sources of sediment. Constructing barriers to sediment transport, such as buildings and bulkheads, hinders wave and wind processes from moving the sand both landward and seaward. In addition, the presence of these structures blocks the migrating dune itself. Dune processes and migration is also impeded by practices, such as paving over the dune and the area to its rear, planting thick vegetation cover, and constructing buildings on and behind the dune. These practices eliminate potential sediment sources and affect dune migration. There will always be considerable pressure to build residences and commercial structures as close to the beach as possible. Without land use controls, it is unrealistic to assume that processes on the landward side of the dune zone will be allowed to function naturally. It is likely that such areas will be paved, covered over with lawn grass, or otherwise stabilized, and sediments which would otherwise be delivered inland will be trapped.

If any sand is delivered inland, it is likely that it will be rapidly bulldozed back into the dune, or worse, removed to provide landfill.

More rigorous performance standards are required to insure the maintenance of the dune as it migrates inland. These standards will have to apply to construction of buildings in the dune zone, to the use of engineering structures to protect against erosion, to any destruction of the dune form, to reconstruction of buildings following storm damage, and to the siting of necessary service facilities. These new standards will have to be applied to the dune zone and to the area to its rear. In order to establish specific standards, it is useful to conceptualize the rationale for employment of the standards and to demonstrate how they are effective in their designed role.

4.3.2 Buildings

Dense development of the shoreline has resulted in a desire by local residents to maintain and protect their property in the face of shoreline erosion. However, the construction of permanent facilities on the shoreline is incompatible with barrier island dynamics. A migrating dune may soon bury the structures where they are built directly on the ground (Figure 4-1). If the structures are not removed, they will eventually become unsupported when the dune/beach contact migrates to the location of the house. The dune could be bulldozed away from the buildings, but this would diminish its effectiveness as a form of protection. Further, the migration of the barrier island would inevitably place the structures in jeopardy.

The problem of flooding and overwash can be alleviated by building the structures on pilings. This option also has the advantage of providing less interference with natural processes. For these reasons, many of the more recent buildings constructed at the shoreline have been built on pilings. A great impetus for construction on pilings have been provided by the Federal Flood Insurance Program requirements to maintain minimum first floor elevations. However, although these structures may be protected from coastal hazards longer than buildings emplaced directly on the ground, they will eventually become unsupported when the sloping foreshore of the beach migrates to their location and they will be destroyed (Figure 4-2). Further, when these structures are close to the beach they reduce the usefulness of the beach for recreation by reducing the carrying capacity of the beach for bathers and by being unaesthetic.

4.3.3 Infrastructure

Support facilities (which include roads, parking areas, sewer systems, power lines, etc.) have to be maintained free of the destructive and beneficial effects of overwash and sand migration. Like houses, they must be durable enough to withstand hurricane forces. To many, this implies the implementation of "permanent" construction materials and methods such as the use of asphalt for roads and parking areas. However, impermeable surfaces, such as paved parking lots and roads, actually favor flooding and overwash. There will be little

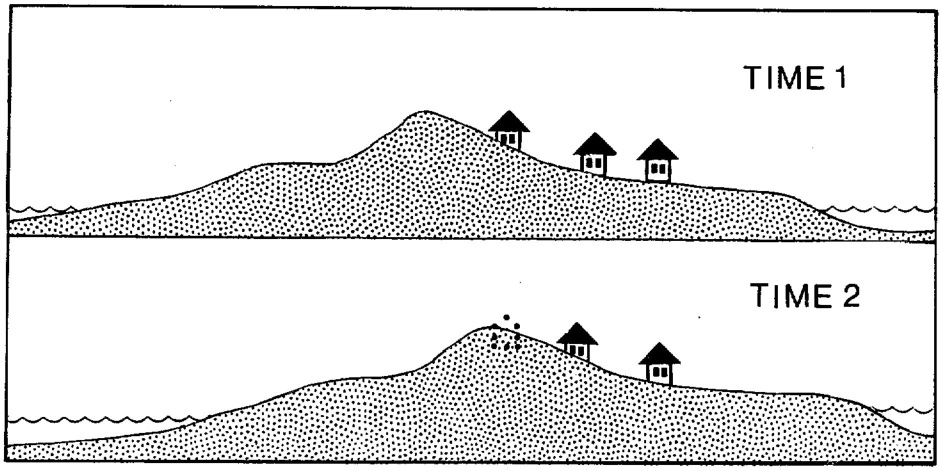

Figure 4-1. Burial of fixed facilities by migrating dune. In many cases, the bayside of the barrier island would be developed, and the buildings might have to be located further inland (Nordstrom and Psuty, 1978).

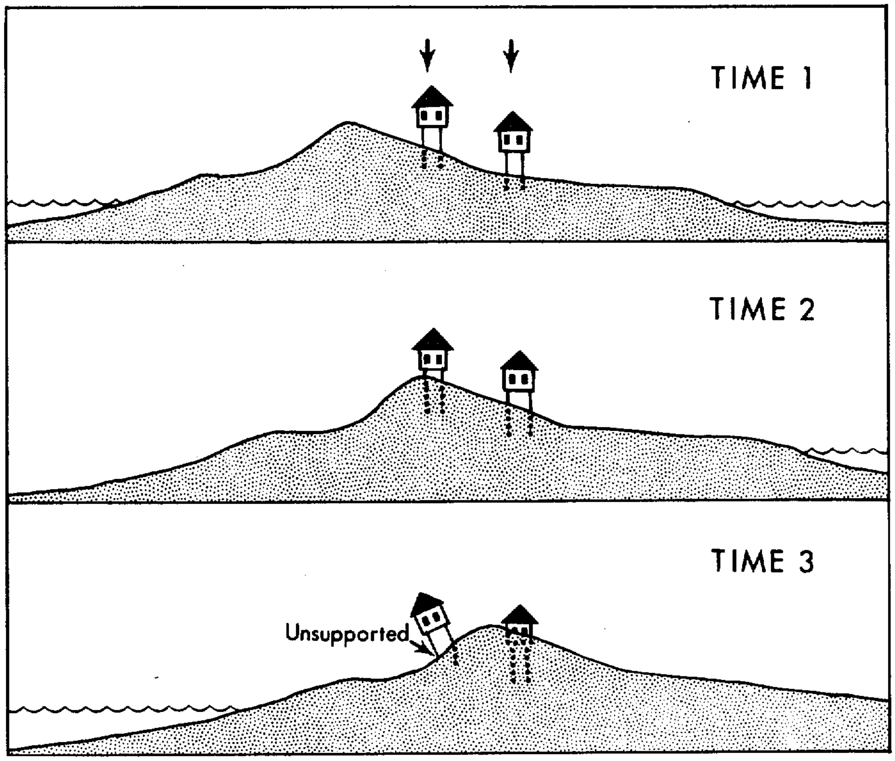

Figure 4-2. Migration of barrier island through time showing incompatibility of locating permanent structures (even on pilings) (Nordstrom and Psuty, 1978).

percolation of flood waters into the ground through these surfaces, and they will act on channels for the delivery of overwash and of entrained sediments considerable distances inland. On a narrow barrier island, the water may reach the bay. The chances for destruction of buildings may thus be increased and sediments may be lost to the bay more rapidly.

4.4 Current Performance Standards

4.4.1 Buildings

Many engineerings improvements which are designed to make structures more able to withstand storm damage have been identified (Collier, et al., 1977; Machemehl, 1978; Pilkey, Neal, and Pilkey, 1978). These improvements should lessen damages and thus lessen the costs of providing insurance. However, "permanent" buildings are not necessarily compatible with barrier island migration. Such structures should be removed when they are damaged as a result of storm conditions. Although the practice of condemning unsafe structures may be invoked, it does not appear to require the removal of the structure. The addition of a removal clause to the condemnation procedure should be undertaken. Removal (and construction) of houses in the dune zone may cause considerable disruption of the vegetation and a lowering of the dune surface. Accordingly, sand stabilization techniques such as sand fences and dune grass plantings should be employed wherever structures are removed.

As in the case of temporary excavation in the dune, it may appear that the use of pilings will not have an adverse effect on the beach/dune profile, vegetation, or the processes that maintain the equilibrium characteristics of this location. However, wind vectors will be altered by both the buildings and the pilings. The size of the structures, the number of structures, and the width and spacing of pilings are important factors to be considered. To date, no study has been made of these effects in sufficient detail to suggest at what point the structures will significantly interfere with natural processes. However, it is clear that the smaller the structures and the less dense they are, the less interference they offer to the wind and waves as well as the sediment transported by these processes. The condominiums in the northern portion of the town of Sea Isle City offer a classic example of localized changes in wind vectors due to the effect of massive structures in the way of the wind. Eddies created by these structures result in the localized onshore wind in their lee even when the regional wind blows offshore. Considerably more sand is transported inland at this location than would occur under natural conditions,and the boardwalk-road fronting the structures has been artificially maintained by earth-moving equipment.

The height above the ground to which houses in coastal areas should be elevated has not been satisfactorily determined. In accordance with Federal Insurance Administration policies, performance standards developed for protection of coastal structures generally specify that the minimum first (habitable) floor elevation should be above the elevation of the highest calculated breaking wave cresting on a 100 year storm tide (Collier, et al., 1977; Machemehl, 1978). This elevation may in fact be very high. New Jersey data (Figure 2-6) indicate that the 100 year storm surge is about 10 feet above mean sea level. The deep water wave height associated with a 100 year storm is also about 10 feet, although the breaking wave height for that wave would be about 18 feet, depending on the slope of the beach and nearshore. The total height, therefore, for a breaking wave plus storm surge is in the range of 27 to 28 feet above mean sea level. The first floor elevation of a house built to FIA specifications would have to be on the order of 30 feet above MSL. If the ground surface is 10 to 20 feet above MSL, the house would have to be 10 to 20 feet above the surface. There is little doubt that 20 feet above the surface would be considered an excessive requirement by homeowners and contractors.

Other methods for establishing first floor height requirements are based on the desired objective for raising houses on pilings (Table 4-2).

Table 4-2. Height requirements for 1st floor depending on management objectives.

Objective	Means of Determination	Height above Surface*
permit overwash	qualitative	5 - 10 ft.
permit dune migration	profiles	10 - 20 ft.
permit beach migration	profiles	8 - 12 ft.
protect against 100 year storm	runup curve	10 - 20 ft.
protect against 50 year storm	runup curve	5 - 15 ft.
reduce interference with wind	qualitative	high rather than low
allow vegetation growth	qualitative	high rather than low

*Height solution given as a range because ground surface height above MSL varies.

A qualitative examination of the objectives indicates that 10 feet is a representative elevation for the first floor of houses built on pilings. This height would certainly allow overwash, protect against a 50 year storm in many locations and allow the beach to migrate beneath the house. It would not, however, permit the dune to migrate beneath the house. Furthermore, a 10 foot requirement would probably not allow enough light beneath the house to favor plant growth. In spite of these drawbacks and despite the lack of information concerning first floor elevation requirements, the 10 foot minimum would appear to represent a reasonable first order approximation.

The first floor minimum height requirements of houses in coastal areas should be the subject of additional research. The significance of this elevation as it affects wind velocity and sediment movement must be determined. In addition, first floor elevations along with the width of the structure must be examined to decide what elevation is sufficient to provide for the growth and maintenance of vegetation below the building.

Collier, et al. (1977) and Machemehl (1978) also suggest a maximum ratio of pile spacing to pile diameter of 8 to 1. These and other suggestions such as specifications on the density of pile bracings and the type of foundations must be examined to insure that their recommendations are compatible with natural processes.

The Federal Flood Insurance Administration and some states allow the use of breakway walls at ground level to create temporary enclosed spaces. In some cases, wind/sand screens are allowed (Collier, et al., 1977). These will of course interfere with sand transfers. Here, then, is one clear cut instance where an alteration to existing regulations is indicated.

4.4.2 Support Facilities

Permeable surfaces such as lawns or graded parking lots will allow for percolation and thus deposition. This reduces the distance the overwash will travel inland. Sediment may thus be deposited close to the beach forming an elevated barrier to further flooding. However, permeable surfaces may still have to be maintained free of moving sand or they may eventually no longer serve their intended purpose.

Water, sewage, telephone, and electrical connections could be kept underground to minimize interference. Surface support structures with impermeable surfaces may be elevated on pilings (if cost effective) so that they do not interfere with natural processes. These elevated support structures would then be subject to the same constraints as elevated buildings. Other service structures constructed on the ground, such as roads and parking areas, should be relocated farther inland when the seaward portions become unserviceable through erosion or burial by the migrating dune. Such facilities should be kept to the absolute minimum. This can be accomplished by control of the number of buildings and vehicles allowed on the barrier island. Incentives which may be used to control facilities on the barrier islands are presented in Section 4.5.1.

4.5 Identifying Compatible Uses

Basic principles have been identified which establish fundamental attitudes toward coastal resources, how these resources are used, and how public decisions are made on the use of the coast and its resources (NJOCZM, 1976). These include:

- maintain or improve productivity of marine resources;
- devote shoreline to activities that depend on a waterfront location;
- respect and protect resources of the natural environment;
- maintain scenic resources;
- accommodate residential, commercial, and industrial development and respect the natural environment;
- increase public access and protect existing public rights;
- employ buffers to separate development from valuable resources and mitigate impacts; and
- consider regional and site specific characteristics and impacts.

The above considerations are consistent with the concept of a Dune Management District. Moreover, a Dune Management District is designed to afford protection by allowing the beach and dune to achieve certain dimensions. There is nothing in the principle of Dune District Management which implies restriction of any one type of coastal development. Accordingly, certain uses which have been identified as inconsistent with barrier island location on aesthetic or economic grounds may not be any more inconsistent with barrier island processes than uses which may be identified as being more desirable according to the above criteria. Therefore, rather than identify a way of eliminating any one particular use, it is important to examine criteria which may be used to control all uses to insure that the location, method of construction, and density of structures required by these uses are consistent with the principles of the establishment of a dune district.

4.5.1 Activity Mechanisms for Control

One objective of barrier island management is to direct land holdings within the dune district into public ownership and to reduce the numbers of structures allowed on the barrier islands. The basis for land transfer involves either prevention of use for the reasons of safety and welfare using police power without compensation or purchase of property for the public good. If public purchase is to be the mechanism for transfer of land, funds must be provided for purchase, and incentives to sell must be created. It has been demonstrated that the threat of storm hazard provides little or no significant incentive to leave for shorefront residents (Mitchell, 1974). Therefore, legal and economic incentives must be found. These will not necessarily accomplish the objective, however, because some people will always wish to locate by the sea for aesthetic considerations. For such people, money alone will not provide a sufficient incentive to relocate. However, it appears that economic incentives combined with legal controls can be effective.

Economic considerations can be conceptualized as either incentives (increasing the value of locating elsewhere) or disincentives (diminishing the value of shorefront properties). The latter would reduce the compensation required to buy damaged or condemned structures. Economic incentives include the following:

- low interest mortgages in inland areas;
- payment of relocation expenses; and
- low taxes in inland locations.

These incentives to move are not likely to be as successful in controlling development as economic "disincentives". These include:

- elimination of government subsidies for flood insurance; and
- elimination of any form of government aid for erosion control.

It is estimated that these two changes in federal and state policy (particularly point 2) would profoundly affect the perceived value of coastal property, although there is no empirical evidence to support the hypothesis. If they were implemented, a greater burden (or all) of the cost of property protection and property loss would fall on the owner.

Another approach to limiting development in the coastal zone involves the use of legal mechanisms which can be created through the establishment of local ordinances. The state, however, should provide some guidelines to the municipalities in regard to the creation of these ordinances in order to create a uniform approach to controlling land use. Legal mechanisms for limiting development include:

- limiting shorefront homes to principal residences;
- preventing rebuilding of damaged structures;
- condemning unsafe structures;
- implementing more rigorous zoning standards; and
- implementing more rigorous building codes.

Many of the control mechanisms identified above may be rather difficult to implement. The economic, social, and legal implications are profound and well beyond the scope of this report. However, there is evidence that such mechanisms will be employed to an increasing degree in the future.

Section 5 - Coastal Resource and Development Policies

5.1 Introduction

In order to effectively manage the dune zone and the barrier island, relevant management policies must be developed by coastal zone administrators. This section provides guidelines for legislation designed to control development on the barrier islands. The format employed here closely follows that used in Chapter 4 of *State of New Jersey Coastal Management Program Bay and Ocean Shore Segment* (NJDEP-OCZM, 1978). Following that format, this discussion shall focus on Location Policies (Section 5.2) and Use Policies (Section 5.3). Resource policies certainly apply to the problem of dune management but they are not treated here because the Resource Policies presented in the NJDEP-OCZM (1978) report comply with the concepts presented herein. In order to conform to DEP policies, the terminology used in this section follows the definitions presented in Chapter 4, Section 2.3 of NJDEP-OCZM (1978).

The policies described in this section apply to two areas: 1) the Dune Management District; and 2) the areas landward of the Dune Management District referred to hereafter as the Barrier Island Zone. Because the shoreline is migrating, it is necessary to treat these two areas in relation to each other. Eventually, the Dune Management District will migrate into the area to its rear, and that area will be subject to the policies which apply to the Dune Management District. The policies which govern the entire barrier island, therefore, should not conflict with, but rather should support the Dune Management District policies.

Another area which should be recognized is the Headland Zone where the upland meets the ocean. This zone which extends from Manasquan to Long Beach is characterized by a cliffed shoreline where dunes are largely absent. Because of the higher elevations of much of the upland area, protection against flooding is not always an important consideration and, therefore, it is not necessary to implement a Dune Management District in much of the Headland Zone. Shoreline erosion does, however, continue in this area. Coastal planning should, therefore, consider the use of setback limits to reduce the potential for loss of property. Because of these peculiarities, many of the policies developed for the Barrier Island Zone are applicable only to the portions of the Headland Zone characterized by low elevations.

5.2 Location Policies

The Location Policies are designed to replace Sections 3.2.13 and 3.2.14 in NJDEP-OCZM (1978). The policies which apply to Other Special Areas, to Water Areas, to Water's Edge Areas, and to Land Areas are not revised since they are generally consistent with the policies which apply to the Dune Management District and to the Barrier Island Zone.

5.2.1 Dune Management District

5.2.1.1 Policy

a) The boundaries of the Dune Management District are considered to be dynamic and migrate inland in response to rising sea level and a negative sediment budget.

b) The boundaries of the Dune Management District shall be reviewed every 10 years to determine if boundary relocation is necessary. In addition, boundary review should take place following a major storm if extensive erosion has resulted.

c) Dunes should be allowed to form and to migrate in a natural fashion. However, dune building through artificial means, such as planting dune grass or erecting sand fences, may be encouraged. Where present dune lines are breached by beach access gaps, these gaps should be closed.

d) Natural processes should not be interfered with. Overwash fans should not be bulldozed to relocate the sediments. The growth of natural vegetation should be encouraged. Bulkheads or other similar engineering structures are not permitted.

e) All new construction in the Dune Management District is prohibited. This includes construction of buildings or support structures and expansion of existing structures.

f) Existing housing is allowed in the Dune Management District.

g) Any existing structure in the Dune Management District which sustains damage equal to or in excess of 50% of its assessed value shall be condemned and removed.

h) Access to the beach through the dune area shall be via designated walkways which are maintained in such a way so as not to lower the dune.

i) Access roads, driveways and parking areas may continue to be used until they are no longer functional. When overwash occurs, any clearing of the areas to allow continued usage is not permitted. When these areas are no longer functional, access to the housing should be accomplished via common walkways.

j) Any vacant land should be converted to public land through direct acquisition, transfer of development rights, donation, or any other such mechanisms.

5.2.1.2 Rationale

Dunes play an important function as part of the total beach/dune profile by providing a natural barrier to flooding and a sediment reservoir which buffers rates of erosion. In addition, it is becoming increasingly difficult for municipalities to cover the expense of engineering or beach nourishment projects. The creation of a Dune Management District is an appropriate solution to the financial problems associated with shoreline management. The policies presented here are designed to create a Dune Management District in which natural processes are impeded as little as possible.

5.2.2 Barrier Island Zone

5.2.2.1 Definition

The Barrier Island Zone is that portion of the barrier island or barrier spit that lies inland from the Dune Management District.

5.2.2.2 Policy

a) New or expanded residential development in the Barrier Island Zone is conditionally acceptable provided that the following performance standards are compiled with:

   i. All buildings should be elevated on adequately anchored piles or columns.

   ii. A minimum elevation for the first habitable floor and an optimum ratio of pile spacing to pile diameter shall be established by each locality. These requirements shall be determined by considering Federal Flood Administration construction recommendations and the requirements to maintain the integrity of the dune.

b) Natural processes should be subjected to minimal interference. Overwash fans may be bulldozed, but under no circumstances should the sediment be removed from the system.

c) New development, including hotels, restaurants, or stores is discouraged.

d) Any construction project should be reviewed by a DEP review board on a unit by unit basis to insure that it complies with performance standards.

e) Day users should be encouraged to park off the islands, and appropriate public transportation must be made available to connect off-island parking lots with the beaches.

f) A post-disaster redevelopment plan should be created by municipalities immediately. Factors to be considered should include development density, construction standards, and support facilities network. This plan should be closely adhered to in the event that a high intensity storm destroys large portions of the non-natural barrier islands.

5.2.2.3 Rationale

Whereas all of New Jersey's barrier islands are developed to varying degrees, the overriding policy emphasized here is a limited or no growth policy. The acceptability for development continues to be determined by the Location Policy criteria for development on Land Areas (NJDEP-OCZM, 1978, Section 3.5). However, it is suggested that most areas on barrier islands be considered as low growth or, at most, moderate growth categories. Heavy development of the barrier islands is not compatible with the objective of allowing natural migration to take place.

5.3 Use Policies

5.3.1 General

There are many types of uses that are covered in NJDEP-OCZM (1978). Only a few modifications in the Use Policies are necessary to comply with performance standards presented in Section 4 of that report.

5.3.2 Dune Management District

5.3.2.1 Policy

a) New or expanded development of any type is prohibited in this area.

b) Current usage is permitted until the structure or structures are damaged beyond 50% of their assessed value. At that time, the structures are condemned and they should be removed.

c) Recreational usage is restricted to access to the beach.

d) The federal, state, and local governments, as well as conservation groups, are encouraged to acquire existing vacant land in this zone.

5.3.2.2 Rationale

In keeping with Location Policies presented in Section 5.2. Use Policies reflect a no development approach in the Dune Management District. Any further development in that area adjacent to the bea... will impede natural processes. Where that construction occurs, dune development will be hindered and the value of the dunes will be lost. It is in the interests of all persons concerned with coastal policy to promote the creation of a dune zone.

5.3.3 Barrier Island Zone

5.3.3.1 Policy

a) All new housing should be built on pilings so as to minimize interference with natural processes.

b) CAFRA rules requiring the review of planned developments of greater than 25 units should not apply. All construction projects on the barrier islands should be subject to a review process.

c) All public and private resort/recreation development adjacent to coastal waters must provide for reasonable public access to the beach.

d) Hotel-motel developments are conditionally acceptable in the Barrier Island Zone, but they are encouraged to locate on the mainland.

e) New or expanded public facility development is conditionally acceptable in the Barrier Island Zone according to existing provisions.

f) In the Barrier Island Zone, new roads and parking areas are subject to NJDEP rules.

g) New or expanded industrial-commercial development is discouraged in the Barrier Island Zone.

5.3.3.2 Rationale

Use Policy for the Barrier Island Zone should be compatible with Use Policy for the Dune Management District. Natural processes should be allowed to operate in the Barrier Island Zone, although some interference is permitted. Any extensive modifications of these processes in this zone will limit dune construction and migration. Bulldozing away overwash sediment, for instance, will remove an important source of sediment for landward growth of the dune. In addition, dense development may alter wind patterns to the extend that aeolian sediment transport is significantly altered.

Because the Dune Management District will migrate landward, other areas of the barrier island will successively be included in that district. Management of the Barrier Island Zone is, therefore, necessary so that uses will be compatible with uses in the Dune Management District as it migrates landward. Large-scale development is, therefore, discouraged in the Barrier Island Zone.

Section 6 - Model Dune Management Ordinance

6.1 Introduction

One way of implementing the dune management concepts presented in this report is through the use of dune ordinances. As suggested earlier (Section 4.2.2), certain New Jersey municipalities have already adopted dune ordinances. However, very few of these existing ordinances conform to the objectives of dune management presented in Section 5 of this report. In order to facilitate the creation of dune ordinances, a Model Dune Management Ordinance is presented here. This ordinance represents a modification of a model flood plain management ordinance developed by Maloney and Dambly (1976). The Dune Management Ordinance has been formulated on the premise that legislation to manage dunes will be adopted at the state level and will be based on the Location and Use Policies proposed in Section 5 of this report. A separate ordinance or a permitting procedure is required to regulate development in the Barrier Island Zone.

6.2 Model Dune Management Ordinance

SECTION ONE. STATUTORY AUTHORIZATION, FINDINGS OF FACT, PURPOSE, AND OBJECTIVES.

1.1 Statutory Authorization

The Legislation of the State of ______________________ (state) has in ________________________________ (statutes) delegated the responsibility to local governmental units to adopt regulations designed to protect coastal dunes. Pursuant thereto, the ________________________________ (governing body) of ________________________________ (local unit), ________________________________ (state), does ordain as follows:

1.2 Findings of Fact

a) Areas of ________________________________ (local unit), ____________________ (state) have been designated by the ________________________________ (authorization agency) as a Dune Management District.

b) Long-term erosion in ________________________ (local unit) and periodic inundation results in loss of life and property, health and safety hazards, disruption of commerce and governmental services, and extraordinary public expenditures for flood protection and relief.

c) Flood and associated losses and damage due to erosion are caused in part by the occupancy of hazard areas by uses which are vulnerable to damage by floods or erosion.

1.3 Statement of Purpose

It is the purpose of this ordinance to provide a uniform basis for the preparation and implementation of sound dune management regulation and to further the stated objectives.

1.4 Objectives

a) To preserve the natural protective function of dunes;

b) to protect human life and welfare;

c) to minimize expenditure of public monies for costly erosion control projects;

d) to minimize the need for rescue and relief efforts associated with flooding and generally undertaken at the expense of the general public;

e) to minimize prolonged business interruptions;

f) to minimize damage to public facilities and utilities such as water and gas mains, electric, telephone, and sewer lines, streets, and bridges located in or near high erosion areas.

SECTION TWO. DEFINITIONS

1) Accessory Use - A use customarily subordinate or incidental to, and located on the same parcel as the principle use of any structure or property.

2) Density of Residential Development - The maximum number of residential units which may be constructed on a given amount of land under the existing zoning classification of that land without consideration of the provisions of this ordinance.

3) Fair Market Value - The fair market value of property or structures, as used in the definition of "substantial improvement" shall mean the value as determined by the tax assessor, either (a) before the improvement was started, or (b) if the structure has been damaged and is being restored before the damage occurred.

4) Flood or Flooding - A general and temporary condition of partial or complete innundation of normally dry land areas from:

i. the overflow of inland or tidal waters, or

ii. the unusual and rapid accumulation of runoff of surface waters from any source.

5) Erosion - The wearing away of land by the action of natural forces. On a beach, the carrying away of material by wave action, tidal currents, littoral currents, or by wind.

6) Erosion Control Works - Any man-made construction, such as a dam, levee, bulkhead, seawall, revetment, groin, or jetty designed to alter the flood potential of the body of water on or adjacent to which it is built.

7) Habitable Floor - Any floor capable of being used for living, which includes working, sleeping, eating, cooking, or recreation, or any combination thereof. A floor used only for storage purposes is not a habitable floor.

8) New Construction - Those structures the construction or substantial improvement of which is begun after

______________________________ and which are located
(effective date of this ordinance)
within a new mobile home park, or expansion of any existing mobile home park, where repair, construction or improvement of streets, utilities, and pads equals or exceeds 50% of the fair market value of the streets, utilities, and pads as determined by the Tax Assessor before the repair, reconstruction or improvement has commenced.

9) Person - Any individual or group of individuals, corporation, partnership, association, or any other organized group of persons, including state and local governments and agencies thereof.

10) Structure - A walled and roofed building, other than a gas or liquid storage tank, that is principally above ground and affixed to a permanent site, as well as a mobile home on its foundation. The term includes a building while in the course of construction, alteration or repair but does not include building materials supplies intended for use in such construction, alteration, or repair, unless such materials or supplies are within an enclosed building on the premise. The works "building" and "structure" shall have the same meaning for the purposes of this ordinance.

11) Substantial Improvement - Any repair, reconstruction, improvement or alteration of a structure the cost of which equals or exceeds 50% of the fair market value of the property or structure.

"Substantial improvement" shall also mean any combination of repairs, improvements, reconstruction, or alterations taking place within a period of ______________ years any of which alone
(number)
has a cost less than but which together have a cost equal to or exceeding 50% of the fair market value of the property or structure. Substantial improvement is considered to have occurred when the first alteration in any wall, ceiling, floor, or other structural part of the building commences.

SECTION THREE. GENERAL PROVISIONS

3.1 Lands to which this Ordinance Applies

This ordinance shall apply to all lands within the jurisdiction of ______________ that are depicted on the Official
(local unit)
Zoning Map as being a Dune Management District (DMD).

3.2 Establishment of Official Zoning Map

The Official Zoning Map for ______________ together
(local unit)
with all explanatory matter thereon and attached thereto on the effective date of this ordinance is hereby adopted by reference and declared to be a part of this ordinance.

3.3 Interpretation of District Boundaries

The boundaries of the Dune Management District are determined by using the technique presented in *Coastal Dunes: Their Function, Delineation, and Management* (CCES, 1979). The results thereof shall be plotted on the Official Zoning Map for ______________. Boundaries
(local unit)
for construction or use restrictions set forth within this ordinance shall be determined by scaling distances on the Official Zoning Map. Where interpretation is needed in order to allow a surveyor to locate the exact boundaries of the district as shown on the Official Zoning Map, the Dune District Manager shall make the necessary interpretation.

3.4 Boundary Review

In accordance with the principles cited in *Coastal Dunes: Their Function, Delineation, and Management* (CCES, 1979), the Dune Management District is considered to have dynamic boundaries which move inland in response to rising sea level. Consequently, the boundaries of the Dune Management District will be reviewed every 10 years. In addition, a boundary review will take place following any storm which damages large portions of the district. The boundary review process will be conducted by the Dune District Manager in consultation with members of the municipal planning board, municipal council ________________ (other municipal authorities) ______________ and representatives of the New Jersey Department of Environmental Protection Division of Coastal Resources.

3.5 Compliance

No structure or land shall hereafter be located, extended, converted, or structurally altered in the Dune Management District, without full compliance with the terms of this ordinance and other applicable regulations.

3.6 Abrogation and Greater Restrictions

This ordinance is not intended to repeal, abrogate, or impair any existing easement, covenants, or deed restrictions. However, where this ordinance and another conflict or overlay, whichever imposes the more stringent restrictions shall prevail.

3.7 Interpretation

In the interpretation and application of this ordinance, all provisions shall be: 1) considered as minimum requirements; 2) liberally construed in favor of the governing body; and 3) deemed neither to limit nor repeal any other powers granted under the state statutes

SECTION FOUR. ADMINISTRATION

4.1 Dune District Manager

Pursuant to ______________________ (statute) the ________________________ (local governing body) shall appoint a Dune District Manager (who shall be a registered conservation officer). Said Administrator shall be appointed for ____________________ (number) years to implement the provisions of this ordinance.

SECTION FIVE. DUNE MANAGEMENT DISTRICT

5.1 Application of Provisions

The provisions of this section shall apply to all areas designated as DMD on the Official Zoning Map.

5.2 Requirements within a DMD

a) Within the DMD all new construction shall be prohibited.

b) The expansion of any existing structure is prohibited in any DMD.

c) Reconstruction of any existing structure which has sustained damage equal to or greater than 50% of its assessed value is prohibited.

d) Structures which sustain damage equal to or in excess of 50% of their assessed value shall be condemned and removed from the Dune Management District.

e) The removal of any sediment from the DMD is prohibited.

f) Artificial lowering or narrowing of the dune is prohibited.

g) Destruction of natural vegetation is prohibited.

h) Erosion control works, such as bulkheads and seawalls, are prohibited.

5.3 Permitted Practices

a) Revegetation of bare areas using natural species is encouraged.

b) Access to the beach is limited to designated walkways over the dune. These walkways should be constructed so as not to reduce the dune crest elevation below the height of the adjacent dune crest.

c) Existing housing is permitted and may remain until storm related damage is sufficient to result in condemnation.

d) Existing access roads, driveways, and parking areas may continue to be used until they are destroyed by storms, or until overwash sediment covers them.

e) Home repairs are permitted, provided they do not amount to 50% of the assessed value of the structure. Major repairs costing less than 50% of the assessed value must conform to the following requirements:

   1) Reconstruction of portions of the house must result in elevation of that part of the house on pilings.

   2) The elevation of the first habitable floor shall be ____________________ feet above the (determined according to locality) ground surface.

SECTION SIX. NONCONFORMING USES

A structure or the use of a structure or premises which was lawful before the passage or amendment of this ordinance but which is not in conformity with its provisions may be continued as a nonconforming use subject to the following conditions:

a) No such use shall be expanded, changed, enlarged or altered in any way which increases its unconformity.

b) Any substantial improvement of a nonconforming structure shall be made in compliance with the provisions of this ordinance.

c) If such use is discontinued for ________ consecutive months, any future use of the building premises shall conform to this ordinance.

d) If any nonconforming use or structure is destroyed by any means, including flood, to an extent of 50% or more of its market value immediately prior to the destruction, it shall not be reconstructed.

SECTION SEVEN. PENALTIES FOR VIOLATION

Violation of the provisions of this ordinance or failure to comply with any of its requirements, including violation of conditions and safeguards established in connection with grants of variances or special exceptions, shall constitute a misdemeanor. Any person who violates this ordinance or fails to comply with any of its requirements shall upon conviction thereof be fined not more than $___________ or imprisoned for not more than _________ days, or both, and in addition shall pay all costs and expenses involved in the case. Each day such violation continues shall be considered a separate offense.

Nothing herein contained shall prevent the ______________________ (local unit) from taking such other lawful action as is necessary to prevent or remedy any violation.

SECTION EIGHT. SEVERABILITY

If any section, clause, provision, or portion of this ordinance is adjudged unconstitutional or invalid by a court of competent jurisdiction, the remainder of this ordinance shall remain in effect.

Section 7 - Summary and Conclusions

7.1 Summary of Important Concepts

7.1.1 Physical

a) The beach and dunes together form the beach profile in which sediment is continually being exchanged between the two subunits.

b) Dunes provide a barrier to flooding and they buffer rates of shoreline erosion by constituting a sediment reservoir.

c) The beach/dune system is migrating in response to rising sea level.

d) Much of the shoreline is characterized by a negative sediment budget and is continually eroding, although it may be subject to short-term temporal reversals.

7.1.2 Dune Management Districts

a) Any Dune Management District boundary is assumed to be dynamic because the beach/dune system is migrating inland.

b) In order to be defensible in a court of law, a Dune Management District must be given absolute dimensions which are obtained through the use of scientific theory and empirical data.

c) Dimensions of the Dune Management District involve specific measures of dune height and width, as well as a rate of erosion.

d) Proscribed dune height is obtained by calculating wave runup values.

e) Dune width is determined through a regression analysis with dune height.

f) The width of the Dune Management District equals dune width plus the projected erosion rate for a given planning period.

7.1.3 Implementing Dune Management Districts

a) Because of the dynamic nature of the dune zone, Dune Management District boundaries should be reviewed at predetermined time intervals, or following a catastrophic storm which significantly modifies the beach/dune system.

b) Planning for development in or adjacent to the Dune Management District should accommodate natural shoreline migration by providing for development that is compatible with natural processes.

c) Land use control and construction standards may be implemented through the use of local ordinances.

d) A major objective of dune management should be to transfer private land holdings in the district into the public domain.

e) The acquisition of private land in the Dune Management District can be accomplished if the state and federal governments provide certain incentives for transfer or disincentives to construction.

7.2 Future Research Requirements

The primary objective of this project is to identify a method by which a Dune Management District can be delineated. In examining the possible alternatives, certain deficiencies have been noted and these may be considered as future research needs (Table 7-1). The procedure for calculating a Dune Management District is applicable immediately. However, an important future objective should be concerned with refining the methodology presented here. There is much that is not known about dune processes both on undeveloped and developed shorelines. As information about these processes becomes available, it should be incorporated into the model.

The foremost requirement for the refinement of the procedure is the accumulation of additional data. The first component of the delineation technique is runup. It has been shown that many factors influence runup. However, for this project, it has been necessary to use site specific information about storm surge, wave height, and wave period gathered at Atlantic City for other sites. Whereas the tidal range in New Jersey is sufficiently consistent to allow the use of the Atlantic City data for the entire coast, wave characteristics show greater variability from place to place. In order to improve runup prediction, it would be desirable to obtain wave and storm surge data for several locations along the coast. Storm surge analysis may simply involve an examination of existing data if tide gauges have been functioning at several locations other than Atlantic City for a sufficient amount of time to permit adequate frequency analysis. If this is not the case, the state should install recording tide gauges at several coastal locations and storm surge should be monitored.

Long-term wave information is required for sites other than Atlantic City. Field experience indicates that waves observed at Atlantic City will not have the same characteristics as those seen

Table 7-1. Research needs for refining dune district dimensions for specific shoreline reaches.

Research Need	Suggested Methodology
Model Refinement	
Obtain site specific wave, surge, and storm profile data to define dune district for specific reach.	Field measurement of waves and beach profiles. Use of tide gages to provide data to calculate surge.
Develop overwash and beach/ dune interaction models for New Jersey.	Aerial photo study to determine frequency and quantity of overwash events. Empirical study of sediment movement at selected sample sites.
Determine effects of structures on natural processes and develop performance criteria.	Field measurement of wind and overwash currents at representative structures. Calculations of resulting alternations in sediment budget. Design of more compatible structures.
Develop calculation procedure for wave runup on beaches and dunes.	Engineering design study calibrated with empirical wave runup measurements taken in the field.
Methods of Implementation	
Anticipate results of implementation.	Compare and contrast differences in communities by examining zoning standards and characteristics of dunes and their interactions with man-made features.
Assess performance of Dune Management District.	Field and air photo investigation of beach and dune changes through time to assure that dunes provide protection against design storm.
Standardize procedures.	Compilation and distillation of information gathered in above studies.

at other locations. It is, therefore, important that the state establish a wave monitoring system at several locations along the coast. Once more detailed wave and storm surge information become available, the runup prediction curves should be recalculated in order to increase their accuracy.

A second means of refining the Dune Management District delineation procedure involves calculating the runup for smaller segments of the coastline. It has been shown that beach slope, beach width, and dune slope are important factors in the calculation of runup. These characteristics are certain to vary from place to place. The proposed procedure has been calculated based on storm profiles available for each of four segments. The lack of storm profiles in general has made it impossible to determine runup for more than those four segments. However, because of the variability of beach characteristics, a desirable goal would be to segment the coastline further and determine runup frequency curves for each segment. Segments could be determined either by dividing the coastline on the basis of natural characteristics and location of beach protection structures (Nordstrom, et al., 1977) or through the use of political boundaries. The latter has the advantage that each municipality would have a runup prediction curve of its own and the Dune Management District would be based upon peculiarities of that municipality alone.

Whatever segmentation procedure is utilized, a major requisite is the gathering of beach profile data. The runups used herein are calculated using the typical flat winter profiles because they represent storm conditions in which runup can be expected to be at a maximum. Storm or winter profiles are not universally available for the New Jersey shoreline. Continued beach/dune profiling is necessary in order to refine the model. The profile lines surveyed in this study should be monitored over the long term and the state should consider establishing additional survey lines.

A third means of refining the model involves the development of beach/dune interaction models for New Jersey. The information utilized in this report about dune formation and migration processes comes from areas outside of New Jersey where conditions may be markedly different. While applying that information to New Jersey has helped to understand what processes can be expected to be operative, the responses specific to New Jersey are now known. A historical analysis of shoreline and dune migration is, therefore, required in order to better gauge the relative importance of the processes involved. This could be accomplished through a study of aerial photographs augmented by a field study of sediment movement. Research of this nature would help to determine how dune formation could be enhanced and how dune migration could be accommodated in the proposed Dune Management District.

This report has emphasized that on developed shorelines natural processes are modified by the presence of structures. However, no study to date has examined exactly how such modifications take place. It appears that an ideal study would compare the behavior of dunes on adjacent developed and undeveloped shorelines. This study is essential to understanding the way in which dunes migrate on developed shorelines and the rate of migration. Certainly, knowledge gained from such a study would provide important information towards refining the model.

There is also the opportunity for research in coastal engineering. The Dune Management District is delineated according to an engineering procedure which calculates wave runup. The current calculation technique applies to impermeable engineering structures. While it is not ideal, it is acceptable here because it provides a conservative runup value. A runup on a permeable beach can be expected to be lower because some of the water infiltrates through the sand. To increase the accuracy of the runup prediction technique, runup studies on beaches need to be conducted. Such a refinement would help to increase the precision of runup predictions and would, thus, strengthen the model.

Even though model refinement is considered a necessity, it is suggested that Dune Management Districts delineated according to the methodology presented herein be established without delay. Modifications indicated by future research can be made at the time of the review. At that same time, the performance of the district should also be assessed. This assessment should, for the first planning period, be done very deliberately. Factors to be considered include dune formation and migration, overwash frequency, shoreline erosion, storm frequency, protection afforded to existing buildings, and condemnation procedures. In addition, policies which have been established on the barrier islands outside of the Dune Management District should be reviewed by state officials to assess their compatibility with the regulations existing within the district.

The use of Dune Management Districts represents an important modification of traditional approaches towards coastal management. Once this dynamic management technique becomes an acceptable alternative to using static engineering structures, this approach should be applied to managing the entire barrier island. This is an important consideration because, as houses are removed from the oceanfront portion of the island, development continues along the bayside of the island. A static bayshore is as incompatible with natural processes as a static ocean shoreline. The problem of comprehensive barrier island planning must become the focus of future management efforts in order to ensure that the dynamic approach will be successful.

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Appendix A - Location of New Jersey Beach Survey Lines

Table A-1. Profile datum and subdatum locations.

Profile	Datum*	Subdatum
1	A-37	Telephone pole outside of South Amboy Boat Club (South Amboy)
2	X-36	Northwest corner of white fence, house no. 15 Bayshore Avenue (South Amboy)
3	S-70	Galvanized fence post on southeast corner of chain link fence near filtration plant, Woodhouse Avenue and Blvd. W (Union Beach)
4	3201	Front Street (Union Beach)
5	3201	Bulkhead at the end of Florence Street (Union Beach)
6	3201	Telephone pole #JC 644 UB first TP east of house #741 at Front and Union Avenue (Union Beach)
7	Tidal 4	340° from west edge of galvanized section of shed near inlet gate (Union Beach)
8	Tidal 4	Tidal 4 (Keansburg)
9	G-1	Telephone pole #JC 8310 MDT at 4 W Street on lot east of Shoal Harbor Historical Home (East Keansburg)
10	N-16	Beach Avenue, Post 4947 (Leonardo)
11		Arrowsmith Beach - metal stake (Sandy Hook)
12		East side of north point - metal stake at benchmark (Sandy Hook)
13		North beach - fence post (Sandy Hook)
14		South fishing beach - wooden post (Sandy Hook)
15		South of critical zone - metal stake (Sandy Hook)

*For location of benchmarks, consult Bureau of Geology or U.S. Army Corps of Engineers, Philadelphia District.

Table A-1. Continued.

Profile	Datum	Subdatum
16	6291	Last post on southern end of barricade, east end of Darlington Road (Deal)
17	9212	Light pole #3814, last pole at 5th Avenue on the boardwalk (Belmar)
18	9230	Sea Girt, Rt. 71 between Brooklyn and New York Avenues - 37.4 ft. south of telephone pole #SG 40149 and 23.9 ft. east of Center-line Rt. 71 (Sea Girt)
19	2204	Telephone pole #40006 EH-92W on East Avenue (Bayhead)
20	2638	West side of Rt. 35 between Stephens Place and Newman Place, 10.5 ft. south of telephone pole BT 86-M, TP 41.6 ft., 125° AZ to subdatum (Mantoloking)
21	USACE Line 33-A63	Telephone pole #40009 MG-295 W, Princeton Avenue (Mantoloking)
22	USACE Line 37-1965	Chadwick Beach at corner of Jacobson Lane and Ocean Avenue, 25.8 ft. east of east edge of white two-story building, 117 ft. to end of brick wall (Chadwick Beach)
23	RM3	Light pole JC 97B at east end of 6th Lane (South Seaside Park)
24	Oceanview RM4 (1932)	Oceanview RM 4 (1932) (Island Beach State Park)
25	FLY	328 ft. with Azimuth 105° from FLY, then 98.4 ft. with Azimuth 217° to subdatum (tree stump) (Island Beach State Park)
26	FLY	Third power pole from end of paved road south on the beach (Island Beach State Park)
27	RM3	Telephone pole #33239 at end of 11th Street (Barnegat Light)
28	S67	170.6 ft., 200° Azimuth from telephone pole #P19724 (Barnegat Light)

Table A-1. Continued.

Profile	Datum	Subdatum
29	Q7	147.6 ft., 216° Azimuth from telephone pole #8204 at the end of 80th Street (Harvey Cedars)
30	E67	Telephone pole #1333 at property boundary of house no. 90/92 Long Beach Blvd. (North Beach)
31	5291	Telephone pole #BT 75 at northeast end of 9th Street, 15 ft. at 58° Azimuth from pole (Surf City)
32	5296	38.7 ft. 232° Azimuth of telephone pole #4662 on Ocean Avenue (Brant Beach)
33	5265	Telephone pole #P30249 on 34th Street (Beach Haven Gardens)
34	8205	End of cement wall on 9th Street (Beach Haven Terrace)
35	8207	Telephone pole #T3874 on east side of bay at intersection of Bay and Johnson (Beach Haven)
36	4825	Metal fence stake, 224° Azimuth to chimney of white house with red roof and 204° to middle tower of castle (Brigantine Beach)
37	4821	164.4 ft. at 66° Azimuth from post of split rail fence to northeast corner of picket fence of house #405 on 18th Street (Brigantine)
38	4820	From dead end sign of access road to Sandpiper Motel off of Brigantine Blvd., 298.5 ft. at 64° Azimuth (Junction 2 paths), then 237.9 ft. at Azimuth 242° to subdatum
39	4844	On the boardwalk, second telephone pole north of light pole with "Brighton" Street sign (Atlantic City)
40	USACE Line 89a-1965	Lower horizontal timber on bulkhead (Longport)

Table A-1. Continued.

Profile	Datum	Subdatum
41	USACE GE-10 1963	Telephone pole #5643 between houses no. 304/308 Atlantic (Ocean City)
42	2704	65 ft. north from telephone pole along concrete wall at southern end of sidewalk flush against wall (large hotel, guesthouse building)
43	USACE Line 98-1963	South from telephone pole #35182 on beach, 224° Azimuth to water tower, 43° Azimuth to telephone pole on east side of road, and 40° Azimuth to telephone pole on west side of road (Corson State Park)
44	5736	Telephone pole #ACE 5301 on corner of Neptune and Winthrop avenues (Strathmere)
45	USACE Line 100-1963	1.5 ft. galvanized steel pipe with 0.5 ft. showing above ground (Strathmere)
46	5751	Telephone pole #ACE 37933 on 92nd Street (Townsends Inlet)
47	5751	Fence post on east side of access path at end of 21st Street on the boardwalk; subdatum 101° Azimuth from pavillion corner, 40° Azimuth from flagpole, and 130° Azimuth from telephone pole #7049 (Avalon)
48	5756	Near corner of 48th Street and Dune Drive on the beach, last round post of a broken fence on left side of access path heading southeast to beach, 99.4 ft. from post to subdatum with Azimuth 281°, and Azimuth 260° from broken post to Stone Harbor water tower (Avalon)
49	USACE Line 112-1963	Third bulkhead post north of telephone pole #6126 on 107th Street (Stone Harbor)
50	Stone Harbor	In undeveloped area south of 121st Street eastern end of "No vehicles past this point" sign, normal to damaged end of bulkhead (Stone Harbor)

Table A-1. Continued.

Profile	Datum	Subdatum
51	USACE Line 114-1963	Near path off JFK Blvd. and 10th Avenue, down path near sand fence (subdatum is USACE Line 114-1963) (North Wildwood)
52	USACE Line 115-1963	Top of north side of stairwell on boardwalk going to the beach at 26th Street (Wildwood)
53	USACE Line 119-1963	Near Diamond Beach Motel, 63.3 ft. south of bulkhead on the beach with Azimuth 148° to telephone pole #25553 at the end of the parking lot and Azimuth 78° to concrete corner to the east of parking lot (Diamond Beach)
54	NOS 4962F	From intersection of Mt. Vernon and 2nd Avenue follow into private road, culvert at the end of private road, subdatum 167.3 ft. from culvert at 283° Azimuth to the Cape May Lighthouse (Cape May)
55	USACE Line 128-1965	At intersection of Cape and Lincoln, 15.1 ft. with 305° Azimuth from telephone pole #ACE W-2588 (West Cape May)
56	Surface of Southern Cape May Canal Jetty	Follow shore path from New England Road west toward buoy, then turn right onto access road toward canal, subdatum is old tree trunk (0.33 ft. diameter and 4.5 ft. high)
57	Tidal 4	In center of road leading to North Cape May Canal Jetty, 40.0 ft. from telephone pole #W24934 (North Cape May)
58	Tidal 4	Telephone pole #W8984 at corner of Adelphia Road and Bay Shore Drive, subdatum is steel plug on the south side of pole (Town Bank)
59	5721	At corner of Pierces Point Road and Bayshore Drive, subdatum is midpoint of fence 35.2 ft. from telephone pole #495 W12848 with an Azimuth of 36° (Pierces Point)
60	2791	At corner of Reeds Road and Bayshore Drive, subdatum is telephone pole #ACE TWA 412

Table A-1. Continued.

Profile	Datum	Subdatum
61	RV3082	Subdatum is a 4 in. x 4 in. stake 59.4 ft., with 306° Azimuth from telephone pole #B-49837 at the end of East Point Road near boat rental facility (Moores Beach)
62	2791	Subdatum is 46.9 ft. from telephone pole #B25739 in front of mobile home and 1.5 mi. southeast from the intersection of New Jersey and Remington roads running down Remington Road (Fortescue)
63	2791	Telephone pole on southwest side of intersection of New Jersey and Remington roads, subdatum is steel plate on the northwest side of pole (Fortescue)

Appendix B - Example Problem for Runup Calculation

The following is a sample problem taken from *The Shore Protection Manual* (CERC, 1977) which shows the method that was used in this report to calculate runup.

GIVEN - A smooth-faced levee (cross section shown in Figure B-1) is subjected to a design wave having a period $T = 8$ sec. and an equivalent deepwater height $H'_o = 5$ ft. The depth at the structure toe is $d_s = 4$ ft.

FIND - Using the composite-slope method, determine the maximum runup on the levee face by the design wave.

SOLUTION - The runup on a 1 on 3 slope is first calculated to determine whether the runup will exceed the berm elevation. Calculate,

$$\frac{d_s}{H'_o} = \frac{4}{5} = 0.8, \text{ and } \frac{H'_o}{gT^2} = \frac{5}{32.2(8)^2} = 0.0024.$$

From Figure B-2 for $\frac{d_s}{H'_o} = 0.8$,

with $\cot(\theta) = \frac{1}{\tan\theta} = 3$, and $\frac{H'_o}{gT^2} = 0.0024$, $\frac{R}{H'_o} = 2.8$.

This runup is corrected for scale effects by using Figure B-3 with $\tan\theta = 0.33$ and $H \approx 5$ ft. A correction factor $k = 1.15$ is obtained and

$$R = 2.8\,k\,H'_o = 2.8\,(1.15)\,(5), \qquad R = 16.1 \text{ ft.}$$

which is 10.1 feet above the berm elevation (see Figure B-1). Therefore, the composite-slope method must be used.

The breaker depth for the given design wave is first determined with

$$\frac{H'_o}{gT^2} = 0.0024$$

Enter Figure B-4 with $H'_o/gT^2 = 0.0024$, using the curve for the given slope of $m = 0.050$ (1:20), and find $\frac{H_b}{H'_o} = 1.46$. Therefore,

$$H_b = 1.46(5) = 7.30 \text{ ft.}$$

Calculate, $\frac{H_b}{gT^2} = \frac{7.30}{32.2(8)^2} = 0.00354$. Then, from Figure B-5,

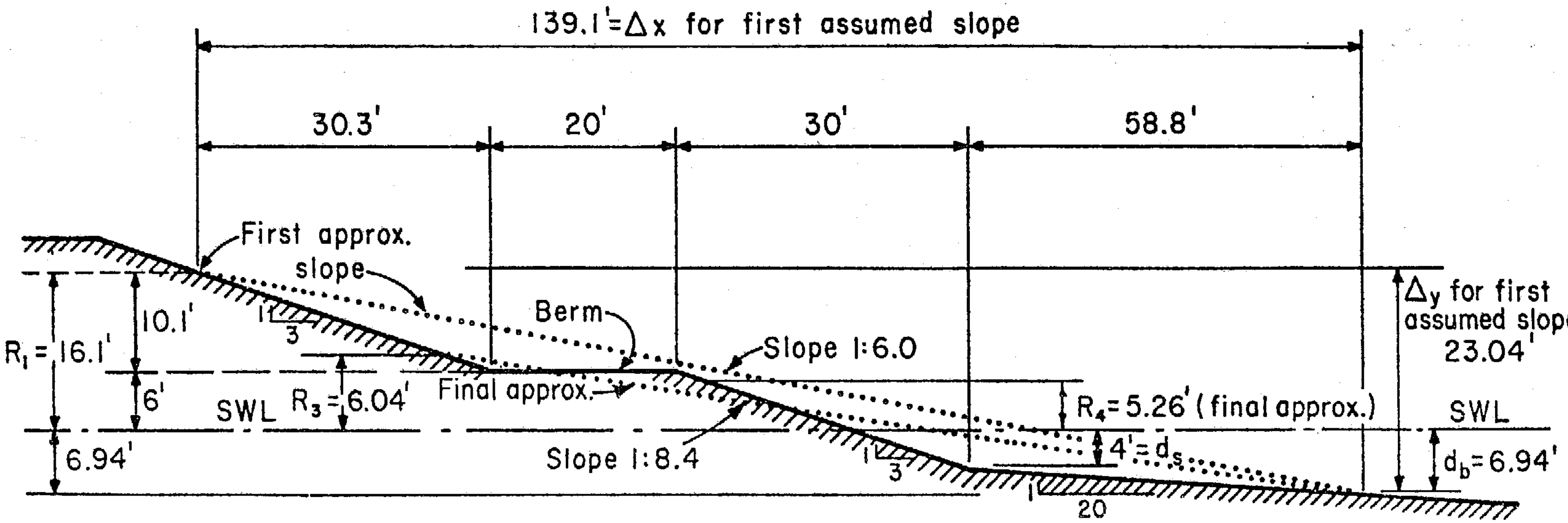

Figure B-1. Calculation of runup for composite slope, example of a levee cross section (from CERC, 1977).

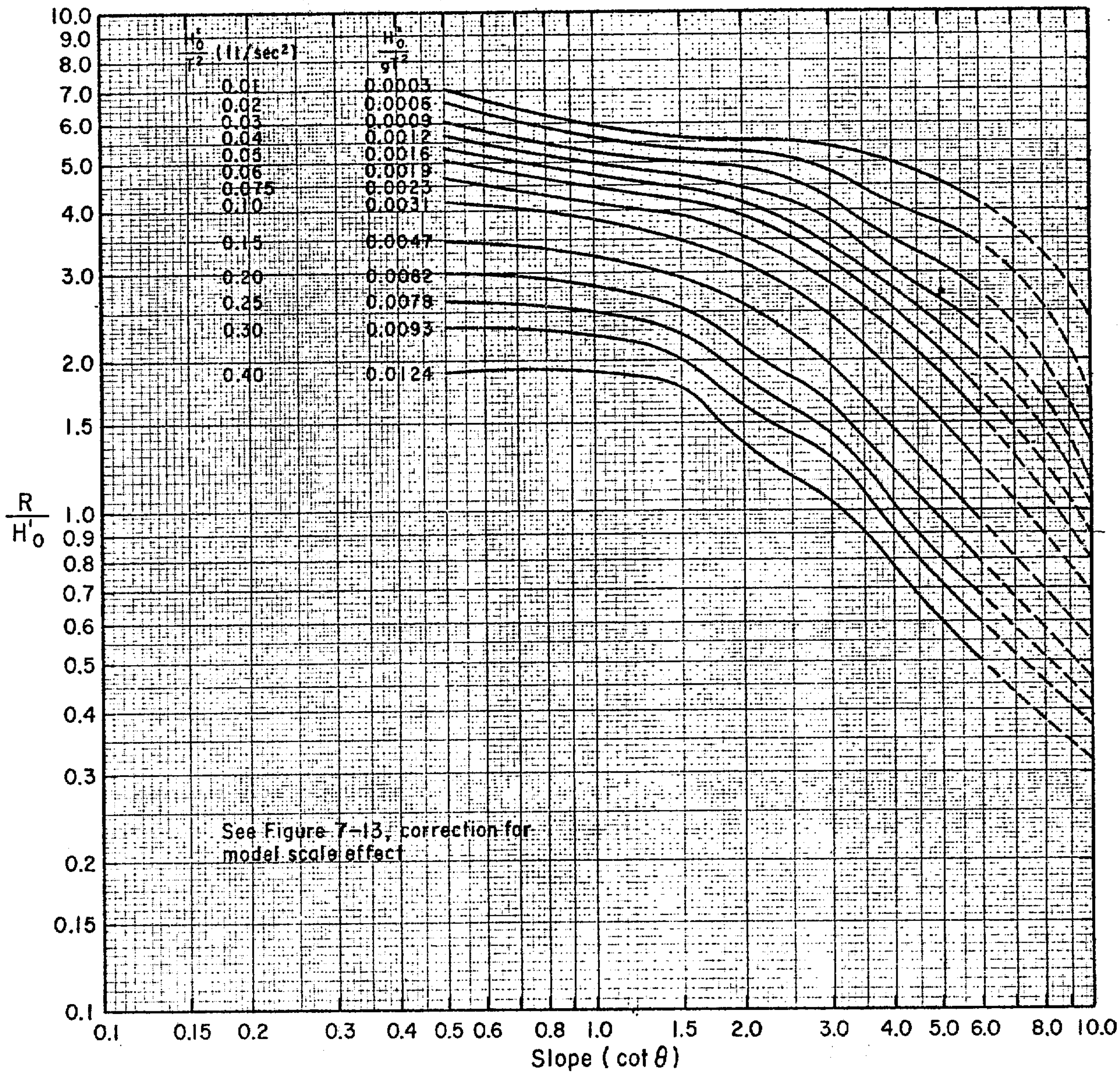

Figure B-2. Wave runup on smooth, impermeable slopes, $d_s/H'o \approx$ 0.80 (from CERC, 1977).

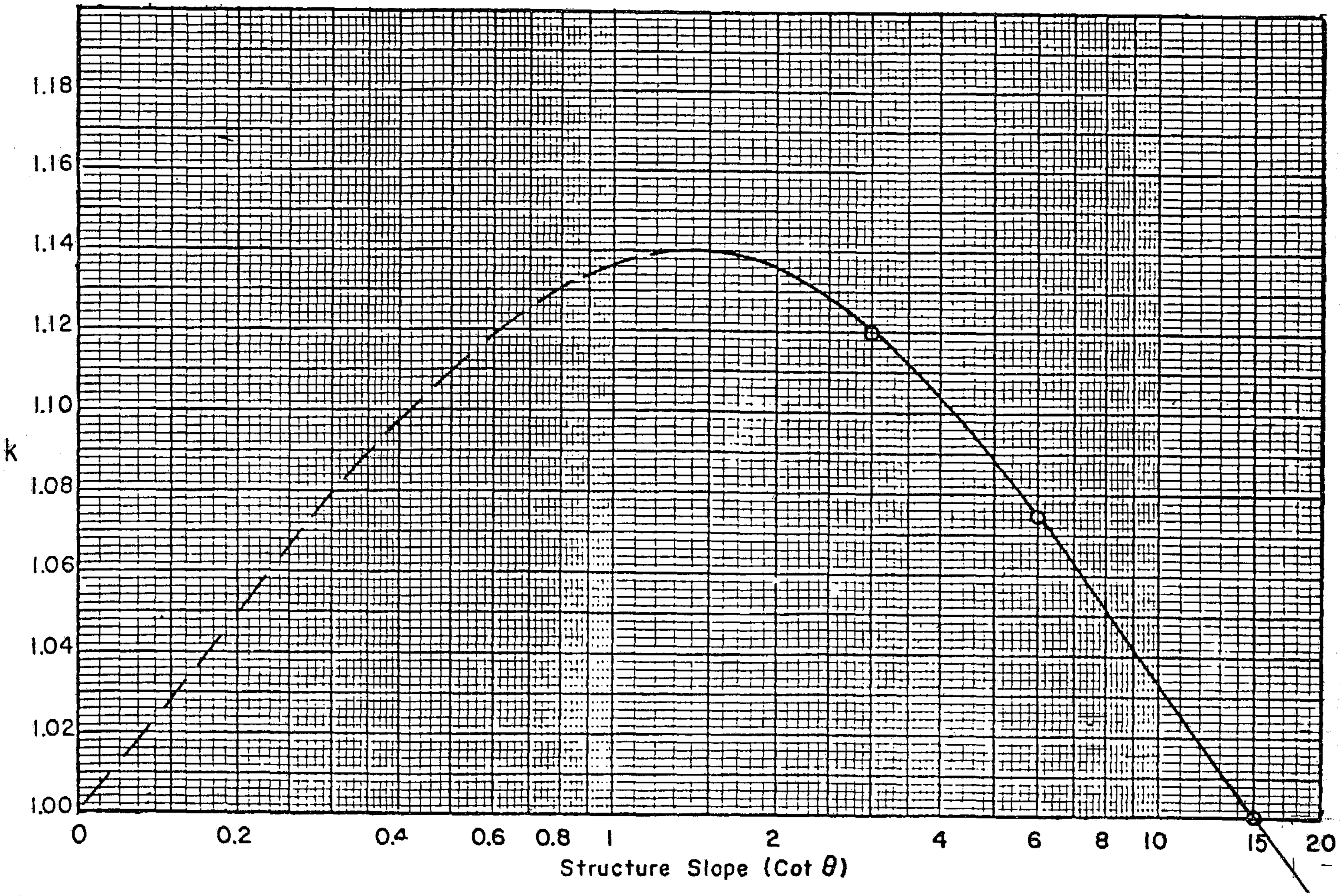

Figure B-3. Runup scale-effect correction factor, k (from Stoa, 1978).

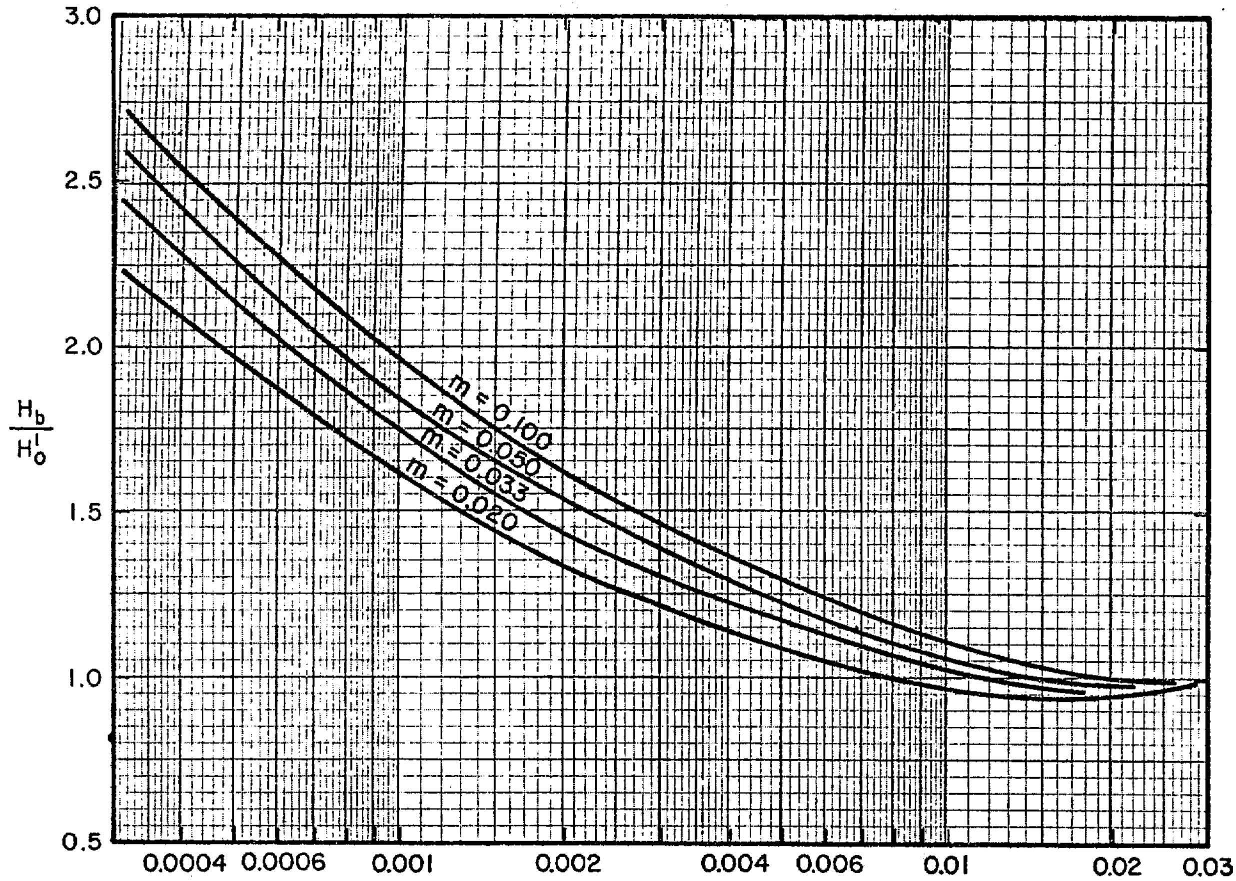

Figure B-4 . Breaker height index, $H_b/H'o$ versus deep water wave steepness, $H'o/gT^2$ (from CERC, 1977).

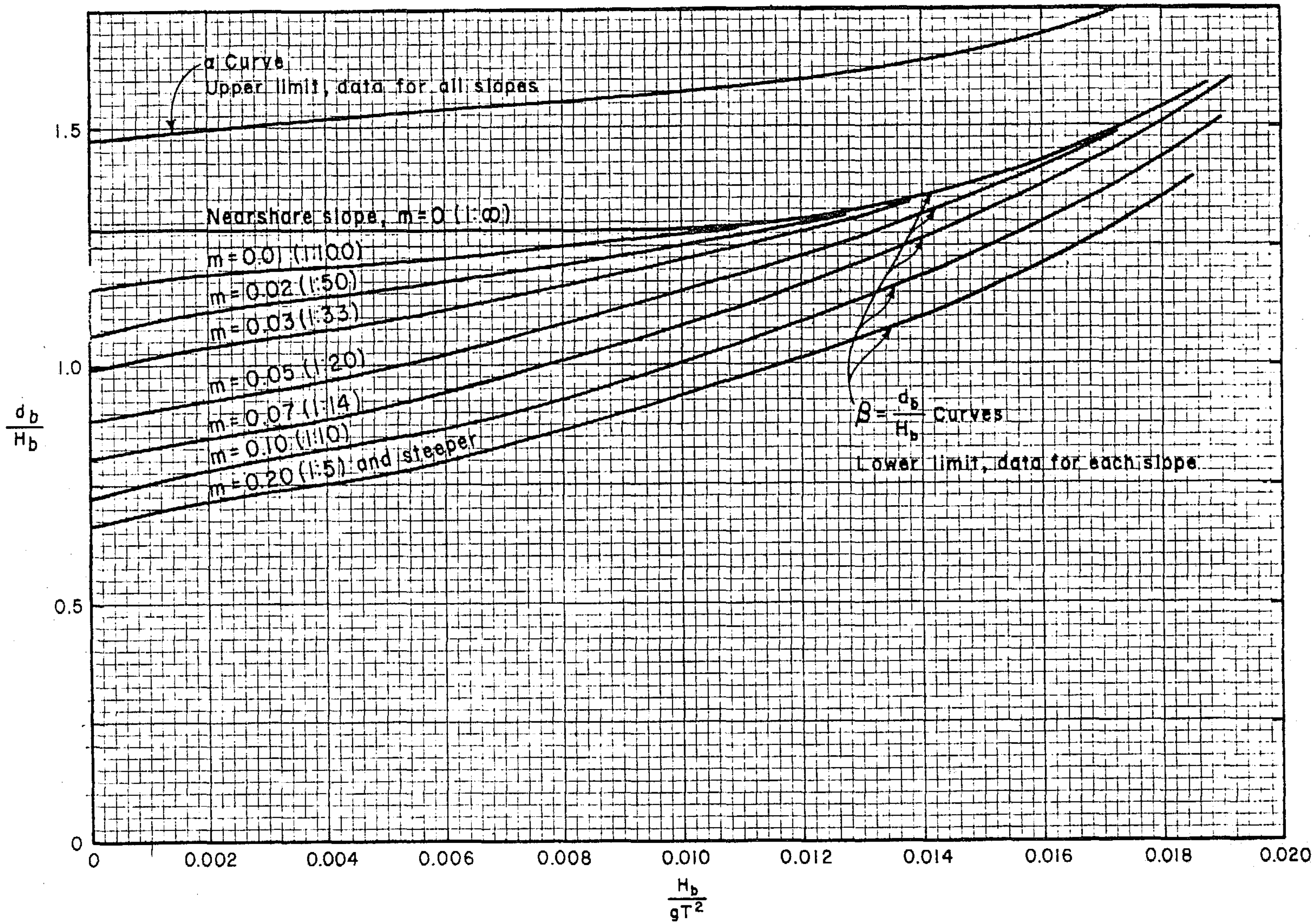

Figure B-5. d_b/H_b versus H_b/gT^2 (from CERC, 1977).

$m = 0.05$, $\frac{d_b}{H_b} = 0.95$, and $d_b = 0.95\ H_b = 0.95\ (7.30) = 6.94$

Therefore, the wave will break a distance (6.94-4.0)/0.05 = 58.8 ft. in front of the structure toe.

The runup value calculated above is a first approximation to the actual runup, and is used to calculate a hypothetical slope that is used to determine the second approximation to the runup. The hypothetical slope is taken from the point of maximum runup on the structure to the bottom at the breaker location (the upper dotted line on Figure B6). Then, $\Delta x = 58.8' + 30' + 20' + 30.3' = 139.1$ ft., and the change in elevation is $\Delta y = 6.94 + 16.1 = 23.04$ ft. and therefore

$$\cot \theta = \frac{\Delta y}{\Delta y} = \frac{(139.1)}{(23.04)} \approx 6.0$$

This slope may now be used with the runup curves (Figure B-2 and B-7) to determine a second approximation to the actual runup. Calculate d_s/H'_o using the breaker depth d_b,

$$\frac{d_b}{H'_o} = \frac{6.94}{5} = 1.39.$$

Interpolating between Figure B-2 and B-7 for

$$\frac{H'_o}{gT^2} = 0.0024, \quad \frac{R}{H_o} = 1.55.$$

Correcting for scale effects using Figure B-3 k = 1.07, R = 1.55 (1.07) x 5 $\approx$ 8.3 ft.

A new hypothetical slope as shown in Figure B-6 can now be calculated using the second runup approximation to determine Δx and Δy. A third approximation for the runup can then be obtained. This procedure is continued until the difference between two successive approximations is nearly zero. The sequence of runup approximations for the example problem is R_1 = 16.1 ft.,

$R_2 \doteq$ 8.3 ft.,

$R_3 =$ 6.04 ft.,

$R_4 =$ 5.26 ft.,

$R_5 =$ 6+ ft.

and the steps in the calculations are shown graphically in Figure B-6. The number of computational steps could have been decreased if a better first guess of the hypothetical slope had been made.

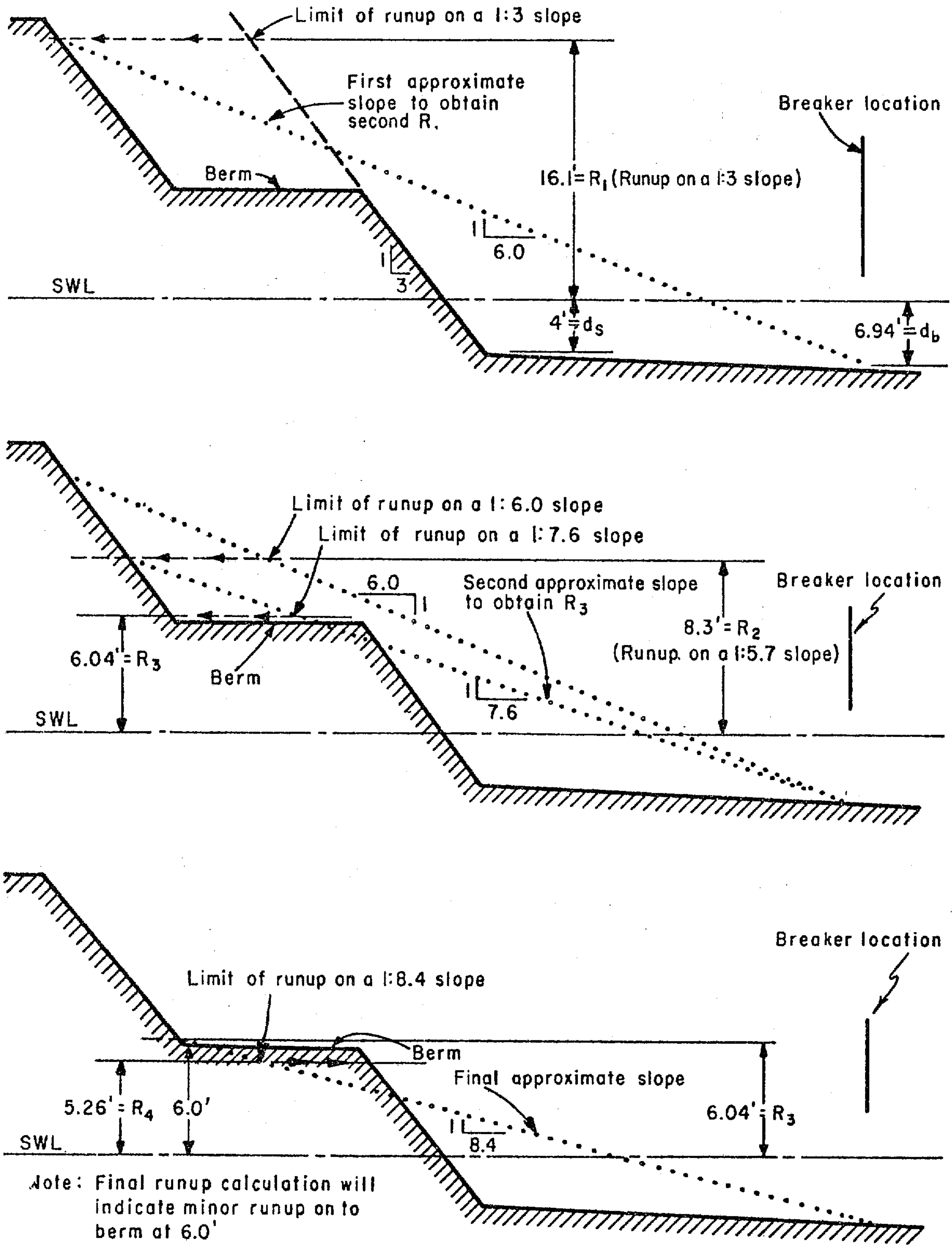

Figure B-6. Successive approximations to runup on a composite slope -- example problem (from CERC, 1977).

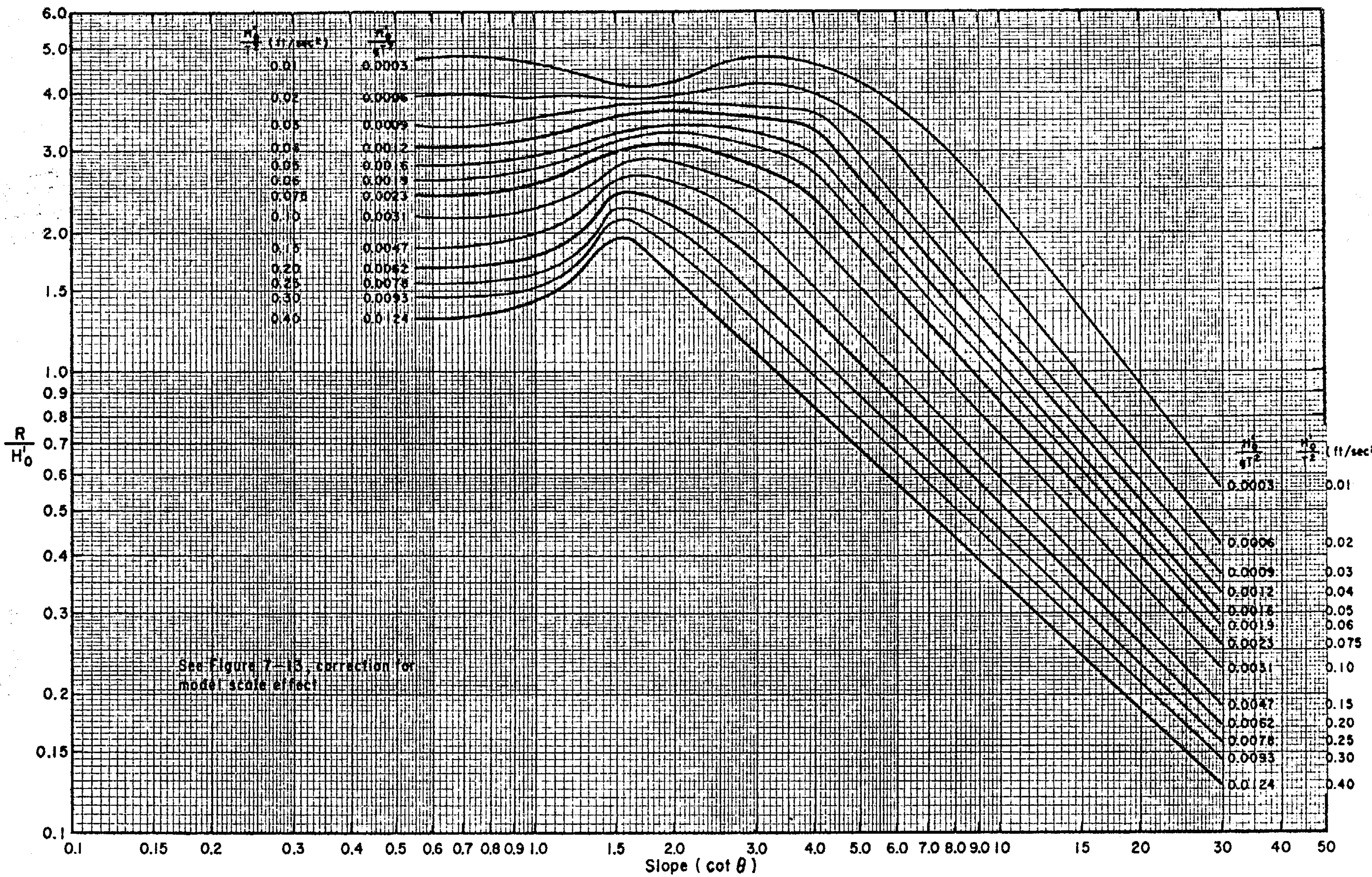

Figure B-7. Wave runup on smooth, impermeable slopes, $d_s/H'_o \simeq 2.0$ (from CERC, 1977).

Using the above methodology, runup values were calculated for each of the design profiles (see Figure 2-4). The following is an example of that calculation for a storm with a 50 year recurrence interval as it applies to Long Beach Island (segment 3 profile on Figure 2-4). Wave and storm data used in the calculation are obtained from Table 2-1.

GIVEN - Storm surge (ds) = 8.9 ft.; wave height (H) = 9.1 ft.; wave period (T) = 13.6 secs.; COT = 16. In this calculation, the depth of structure toe (ds) value used by CERC (1977) was assumed to equal storm surge.

$ds/H = .98$ $\quad$ $H/gT^2 = 0.0015$

$R/H_o = .62$ $\quad$ $K = .995$ $\quad$ $R_1 = 5.6$

Runup (R) is the vertical height above the water level that water from breaking waves will reach. During a storm, the water level is already above normal water level (mean sea level). In order to calculate how high on the beach the water will reach, it is necessary to add the storm surge and the runup together. In this case:

$$d_s + R_1 = R$$

$$8.9 + 5.6 = 14.5 \text{ ft. above MSL}$$

Because this value is above the height at which the dune and the beach intersect (10 feet in this example), the composite-slope method (see CERC example) is used.

It is first necessary to determine breaker depth. For slope $m = 1/16 = 0.0625$, use Figure B-4 to find:

$H_b/H = 1.675$ $\quad$ $H_b = 15.2$ $\quad$ $H_b/gT^2 = 0.0026$

Then, from Figure B-5, find: $d_b/H_b = 0.883$; $d_b = 13.4$.

The wave will break a distance $(13.4-8.9)/0.0625 = 72.4$ feet seaward of the MSL/Beach intercept. The new beach slope is:

$$\Delta x = 72.4 + 188 = 260.4$$

$$\Delta y = 13.4 + 5.6 = 19.0$$

$$\cot \theta = \Delta x/\Delta y = 13.7$$

The Δx is obtained by adding the distance the wave will break in front of the beach, and the horizontal distance the water will flow inland. This inland distance is determined by adding R and d_s. Where this vertical value intersects the profile, read the horizontal value off the x-axis.

Using this new slope, return to Figures B-2 and B-7 to determine runup (R).

$R/H = .734$ $K = 1.008$ $R_2 = 6.7$

This same procedure is repeated until the subsequent values of R converge to the same value. The changes encountered at each step result from the new cotangent θ which is recomputed at each step. In this case, $\cot \theta = 13.7$, or slope $m = 1/13.7 =$

$H_b/H = 1.696$ $H_b = 15.4$ $H_b/gT^2 = 0.0026$

$d_b/H_b = 0.849$ $d_b = 13.1$

$\Delta x = 47.2 + 195 = 252.2$

$\Delta y = 13.1 + 6.7 = 19.8$

$\cot \theta = \Delta x/\Delta y = 12.3$

$R/H = 0.795$ $K = 1.014$ $P_3 = 7.3$

$m = 1/12.7 = 0.0787$

$H_b/H = 1.71$ $H_b = 15.5$ $H_b/gT^2 = 0.00026$

$d_b/H_b = 0.838$ $d_b = 13$

$\Delta x = 51.9 + 198 = 249.9$

$\Delta y = 13 + 7.3 = 20.3$

$\cot \theta = \Delta x/\Delta y = 12.2$

$R/H = 0.838$ $K = 1.016$ $R_4 = 7.7$

$m = 1/12.3 = 0.081$

$H_b/H = 1.71$ $H_b = 15.5$ $H_b/gT^2 = 0.0026$

$d_b/H_b = 0.833$ $d_b = 12.9$

$\Delta x = 49.5 + 202$

$\Delta y = 12.9 + 7.7$

$\cot \theta = \Delta x/\Delta y = 12.2$

$R/H = 0.848$ $K = 1.017$ $R_5 = 7.8$

$m = 1/12.2 = 0.082$

$H_b/H = 1.71$ $H_b = 15.5$ $H_b/gT^2 = 0.0026$

$d_b/H_b = 0.831$ $d_b = 12.9$

$$\frac{\Delta x}{\Delta y} = \frac{48.5 + 203}{12.9 + 7.8} = 12.1 = \cot\theta$$

$R/H = 0.85$ $K = 1.017$ $R_6 = 7.9$

$m = 1/12.1 = 0.0826$

$H_b/H = 1.71$ $H_b = 15.5$ $H_b/gT^2 = 0.0026$

$d_b/H_b = 0.83$ $d_b = 12.9$

$$\frac{\Delta x}{\Delta y} = \frac{48 + 203}{12.9 + 7.9} = 12.1 = \cot\theta$$

$R/H = 0.85$ $K = 1.017$ $R_7 = 7.9$

In this case, final R = 7.9 feet. In order to obtain the height that water will reach during a fifty year storm relative to mean sea level, add the storm surge value to the R:

$R + d_s$ = total water height

7.9 + 8.9 = 16.8 feet above MSL.

The highest elevation on the beach/dune profile would have to be 16.8 feet in order to prevent flooding during this storm.

In order to determine the dune elevation necessary to prevent overtopping during this storm, obtain the backbeach elevation from the profile. In this case, the elevation of the backbeach is 10 feet. The dune height is computed by subtracting the backbeach elevation from the total runup value:

16.8 feet - 10 feet = 6.8 feet.

Appendix C - Glossary

Many of the terms provided in this glossary have been reproduced without modification from Davis (1978), Douglas (1977), U.S. Army Corps of Engineers (1977), and Weigel (1953).

ACCRETION - May be either NATURAL or ARTIFICIAL. Natural accretion is the buildup of land, solely by the action of the forces of nature, on a BEACH by deposition of waterborne or airborne material. Artificial accretion is a similar buildup of land by reason of an act of man, such as the accretion formed by a groin, breakwater, or beach fill deposited by mechanical means. Also AGGRADATION.

AEOLIAN SANDS - (or BLOWN SANDS) - Sediments of sand size or smaller which have been transported by winds. They may be recognized in marine deposits off desert coasts by the greater angularity of the grains compared with water-borne particles. Also EOLIAN SANDS.

ARTIFICIAL DUNE - Accumulation of sediment in dune form which has been built by any non-natural process, such as bulldozing or sand fencing.

ARTIFICIAL NOURISHMENT - The process of replenishing a beach with material (usually sand) obtained from another location. Also BEACH FILL or BEACH NOURISHMENT.

BACKBEACH - That zone of the beach lying between the foreshore and the foredune and acted upon by waves only during severe storms, especially when combined with exceptionally high water.

BACKDUNE - Dune ridge immediately landward of the FOREDUNE.

BAR - A generally submerged embankment of sand, gravel, or other unconsolidated material built on the sea floor in shallow water by waves and currents.

BARRIER BEACH - A single elongate sand ridge rising above the high tide level and extending generally parallel to the coast, but separated from it by a lagoon.

BARRIER ISLAND - Similar to a BARRIER BEACH but with multiple ridges, dunes, vegetated zones, and marsh terraces which extend into the lagoon. In addition, it is commonly detached from the mainland by inlets.

BEACH - The zone of unconsolidated material that is located between the LONGSHORE BAR and the FOREDUNE. In this report, the BEACH is considered to be part of an integrated BEACH/DUNE system in which exchanges of energy and sediment take place between the two subunits.

BEACH ACCRETION - See ACCRETION.

BEACH EROSION - The carrying away of beach materials by wave action, tidal currents, littoral currents, or wind.

BEACH FACE - The section of the beach normally exposed to the action of the wave uprush and backwash. The FORESHORE of a BEACH.

BEACH FILL - See ARTIFICIAL NOURISHMENT.

BEACH NOURISHMENT - See ARTIFICIAL NOURISHMENT.

BEACH RIDGE - A nearly continuous mound of beach material that has been shaped up by wave or other action. Ridges may occur singly or as a series of approximately parallel deposits.

BEACH SEGMENT - A length of shoreline bounded by discernable breaks in shoreline orientation and experiences different equilibrium conditions.

BEACH WIDTH - The horizontal dimension of the beach as measured from the water's edge to the base of the foredune.

BERM - A nearly horizontal part of the beach or backshore formed by the deposit of material by wave action. Some beaches have no berms, others have one or several.

BLOWOUT - A vegetation-free hollow formed by wind erosion on a pre-existing dune or other sand deposit.

BREAKING WAVE - When a WAVE approaches shore, the shallow water allows the ocean bottom to exert drag on the wave retarding its movement and causing it to steepen. When the wave crest has peaked to a point of instability, the wave crest falls forward as a breaker and the energy contained within the wave affects the material it comes into contact with.

BULKHEAD - A structure or partition constructed of timber, sheet piling, rock, etc. designed to retain or prevent sliding of the land. A secondary purpose is to protect the upland against damage from wave action.

CARRYING CAPACITY (VISITORS) - The total number of people that can be sustained on a given land area. Usually described in terms of a minimum area necessary per person.

COAST - A strip of land of indefinite width (may be several miles) that extends from the shoreline inland to the first major change in terrain features.

COASTAL PLAIN - The plain composed of horizontal or gently sloping strata of clastic materials fronting the coast, and generally representing a strip of sea bottom that has emerged from the boundary between the land and the water.

DEBRIS LINE - A line near the limit of storm wave uprush marking the landward limit of debris deposits.

DEEP WATER - Water so deep that surface waves are little affected by the ocean bottom. Generally, water deeper than one-half the surface wavelength is considered deep water.

DELTA - An alluvial deposit, roughly triangular or digitate in shape, formed at a river mouth or inlet.

DESIGN STORM - A representative storm, with specific wave and surge characteristics, that is assumed to occur in a particular study area.

DESIGN WAVE - In the designs of harbors, harbor works, coastal protection structures, etc., the type or types of wave selected as having the characteristics against which protection is desired.

DOMINANT WIND - The direction from which the wind blows with the greatest velocity.

DOWNDRIFT - The direction of predominant movement of littoral materials.

DRIFT (noun) - (1) Sometimes used as an alternative term for LITTORAL DRIFT. (2) The speed at which a current runs. (3) Also floating material deposited on a beach (driftwood).

DUNE CREST - The point or line where the dune's highest elevation is located.

DUNE MANAGEMENT DISTRICT - An artificial area whose boundaries are defined scientifically. Where natural processes are allowed to function without interference and where the dune is protected and maintained.

DUNE SCARP - Located on the seaward side of the foredune. An almost vertical slope along the dune caused by wave erosion.

DUNES - (1) Ridges or mounds of loose, wind-blown material, usually sand.

EBB CURRENT - The tidal current away from shore or down a tidal stream; usually associated with the decrease in the height of the tide.

EBB TIDAL DELTA - Accumulation of sediment, generally sub-aqueous, located at the oceanside end of an inlet.

EBB TIDE - The period of tide between high water and the succeeding low water; a falling tide.

EQUILIBRIUM - A least-work, equal area energy expenditure condition for a land system characterized by imperceptible, short-term physical changes.

EROSION - The wearing away of land by the action of natural forces. On a beach, the carrying away of beach material by wave action, tidal currents, littoral currents, or by deflation.

FETCH - The horizontal distance (in the direction of the wind) over which a wind generates waves.

FLOOD - A general and temporary condition of partial or complete innundation of normally dry land areas.

FLOOD CURRENT - The tidal current toward shore or up a tidal stream, usually associated with the increase in the height of the tide.

FLOOD TIDAL DELTA - Accumulation of sediment, generally sub-aqueous, located at the bayside end of an inlet.

FLOOD TIDE - The period of tide between low water and the succeeding high water; a rising tide.

FOREDUNE - The front dune immediately behind the BACKSHORE.

FORESHORE - The part of the shore lying between the crest of the seaward berm (or upper limit of wave wash at high tide) and the ordinary low water mark, that is ordinarily traversed by the uprush and backrush of the waves as the tides rise and fall.

GRAIN SIZE - A term relating to the size of sediment particles as measured along the intermediate axis. The scale of measurement is either in millimeters or in phi units which is a logarithmic transformation of the millimeter measurement.

GROIN - A shore protection structure built (usually perpendicular to the shoreline) to trap littoral drift or reduce erosion of the shore.

GROIN SYSTEM - A series of groins acting together to protect a section of beach. Commonly called a GROIN FIELD.

HIGH WATER (HW) - Maximum height reached by a rising tide. The height may be solely due to the periodic tidal forces or it may have superimposed upon it the effects of prevailing meteorological conditions. Nontechnically, also called HIGH TIDE.

HIGH WATER LINE - A reference mark on a structure or natural object, indicating the maximum stage of tide or flood.

HOOK - A spit or narrow cape, turned landward at the outer end, resembling a hook in form.

HURRICANE - An intense tropical cyclone in which winds spiral inward toward a core of low pressure with maximum surface wind velocities that equal or exceed 75 mph (65 knots) for several minutes or longer at some points. Barometric pressure in the storm center commonly falls to 950 millibars or lower. The term TROPICAL STORM is used if the maximum wind speeds are less than 75 mph.

INLET - (1) A short, narrow waterway connecting a bay, lagoon, or similar body of water with a large parent body of water. (2) An arm of the sea (or other body or water) that is long compared to its width, and may extend a considerable distance inland.

JETTY - A structure extending into a body of water and designed to prevent shoaling of a channel by littoral materials, and to direct and confine the stream or tidal flow. Jetties are built at the mouth of a river, tidal inlet, or harbor to help maintain depth and stabilize a channel.

LITTORAL CURRENTS - Currents near the shore of an ocean or lake.

LITTORAL DRIFT - The material that moves in the LITTORAL ZONE under the influence of waves and currents.

LITTORAL ZONE - Indefinite zone extending from the shoreline to just beyond the breaker zone.

LONSHORE BAR - A BAR which extends generally parallel with the shoreline and is submerged at least by high tides.

LONGSHORE CURRENT - A current located in the surf zone, moving generally parallel to the shoreline, generated by waves breaking at an angle with the shoreline. Also called an ALONGSHORE CURRENT.

LOW WATER (LW) - The minimum height reached by each falling tide. Nontechnically, also called LOW TIDE.

LOW WATER LINE - The intersection of any standard low tide datum plane with the shore.

MEAN HIGH WATER (MHW) - The average height of the high waters over a 19-year period. For shorter periods of observations, corrections are applied to eliminate known variations and reduce the results to the equivalent of a mean 19-year value. All high water heights are included in the average where the type of tide is either semi-diurnal or mixed. Only the higher high water heights are included in the average where the type of tide is diurnal. So determined, mean high water in the latter case is the same as mean higher high water.

MEAN LOW WATER (MLW) - The average height of low waters over a 19-year period. For shorter periods of observations, corrections are applied to eliminate known variations and reduce the results to the equivalent of a mean 19-year value. All low water heights are included in the average where the type of tide is either semi-diurnal or mixed. Only lower low water heights are included in the average where the type of tide is diurnal. So determined, mean low water in the latter case is the same as mean lower low water.

MEAN SEA LEVEL - The average height of the surface of the sea for all stages of the tide over a 19-year period, usually determined from hourly height readings. Not necessarily equal to MEAN TIDE LEVEL.

MIGRATING BARRIER ISLAND - A barrier island which changes location through time. Migration is generally inland in response to rising sea level.

MIGRATING DUNE - A dune which changes location through time. Coastal dunes generally migrate inland.

MIGRATING SHORELINE - A shoreline which changes location through time.

NEARSHORE (ZONE) - In beach terminology, an indefinite zone extending seaward from the shoreline well beyond the breaker zone. It defines the area of NEARSHORE CURRENTS.

OFFSHORE - (1) In beach terminology, the comparatively flat zone of variable width, extending from the breaker zone to the seaward edge of the continental shelf. (2) A direction seaward from the shore.

OFFSHORE BAR - See LONGSHORE BAR.

OFFSHORE WIND - A wind blowing seaward from the land in a coastal area.

ONSHORE WIND - A wind blowing landward from the sea in a coastal area.

OVERTOPPING - Passing of water over the top of a structure as a result of wave runup or surge action.

OVERWASH - That portion of the uprush that carries over the crest of a berm, a dune, or of a structure.

OVERWASH FAN - Gently sloping, conical accumulation of sediment deposited landward of the beach by overwash processes that result from storm wave activity.

OVERWASH THROAT - Low, narrow area through the foredune where water passes during storms and carries sediment to the overwash fan.

PERMEABILITY - A rock, sediment, or soil property which permits fluids to pass through them.

PREVAILING WIND - The direction from which the wind blows during the greatest proportion of time.

PRIMARY DUNE - See FOREDUNE.

PROCESS-RESPONSE MODEL - A conceptual model that considers processes and responses as separate though closely related aspects of shoreline phenomena. Process elements include: 1) energy; 2) material; and 3) shoreline geometry factors, while response elements include: 1) beach geometry; and 2) beach material factors.

PROFILE, BEACH - The intersection of the active beach/dune ground surface with a vertical plane. It may extend from the top of the dune line to the seaward limit of sand movement.

RETROGRESSION OF A BEACH - (1) A continuing landward movement of the shoreline. (2) A net landward movement of the shoreline over a specified time. Also RECESSION.

REVETMENT - A facing of stone, concrete, etc., built to protect a scarp, embankment, or shore structure against erosion by wave action or currents.

RIPRAP - A layer, facing, or protective mount of stones randomly placed to prevent erosion, scour, or sloughing of a structure or embankment.

SALT MARSH - A marsh periodically flooded by salt water.

SEAWALL - A structure separating land and water area. Primarily designed to prevent erosion and other damage due to wave action.

SECONDARY DUNE - Second dune ridge located landward of the primary dune - see also BACKDUNE.

SEDIMENT - The loose material forming the beach and dune which is composed of different sized particles derived primarily from rocks. The sediment may be transported in the beach environment both by water and by wind.

SEDIMENT BUDGET - An arithmetic relationship between the quantity of sediment added to a shoreline system from potential sources, the quantity of sediment moved to potential sinks, and the quantity of sediment held in storage in the system. If the sediment loses exceed the addition, there is said to be a negative sediment budget. There is a positive sediment budget if additions exceed loses.

SHORE - The narrow strip of land in immediate contact with the sea, including the zone between high and low water lines. A shore of unconsolidated material is usually called a beach.

SIGNIFICANT WAVE HEIGHT - The average height of the one-third highest waves of a given wave group.

SIGNIFICANT WAVE PERIOD - The average wave period of the one-third highest waves within a given group.

SPIT - A small point of land or a narrow shoal projecting into a body of water from the shore.

STABILIZED DUNE - A dune which is maintained in a fixed location by artificial means.

STATIC SHORELINE - A shoreline which remains fixed in one location through time.

STILLWATER LEVEL - The elevation that the surface of the water would assume if all wave action were absent.

STORM SURGE - A rise above normal water level on the open coast due to the action of wind stress on the water surface. Storm surge resulting from a hurricane also includes that rise in level due to atmospheric pressure reduction as well as that due to wind stress.

STORM WIND - High velocity wind or short duration associated with storm conditions.

SWASH - The rush of water up onto the beach face following the breaking of a wave. Also UPRUSH, RUNUP.

TERITARY DUNE - Third dune ridge located landward of the primary and secondary dune. See also BACKDUNE.

THROAT - Breach in the dunes at beach elevation through which washover passes to the backdune area.

TIDAL RANGE - The difference in height between consecutive high and low (or higher high and lower low) waters.

UPDRIFT - The direction opposite that of the predominant movement of littoral materials.

UPRUSH - The rush of water up onto the beach following the breaking of a wave. Also SWASH, RUNUP.

WAVE - A three dimensional form composed of oscillating water particles which represents the horizontal movement of energy through water. The amount of energy contained in the wave depends on FETCH, wind velocity, and the wind duration.

WAVE HEIGHT - The vertical distance between a wave crest and its preceding through. See also SIGNIFICANT WAVE HEIGHT.

WAVE LENGTH - The horizontal distance between similar points of two successive waves measured perpendicular to the crest.

WAVE PERIOD - The time for a wave crest to traverse a distance equal to one wave length. The time for two successive wave crests to pass a fixed point.